TODAY'S TECHNICIAN™

AUTOMOTIVE SUSPENSION & STEERING SYSTEMS

5TH EDITION

CLASSROOM MANUAL

We Support ASE Program Certification Through NATEF®

DON KNOWLES

TODAY'S TECHNICIAN™

CLASSROOM MANUAL FOR AUTOMOTIVE SUSPENSION & STEERING SYSTEMS

FIFTH EDITION

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DON KNOWLES

FIFTH EDITION

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Today's Technician™: Suspension & Steering Systems, 5th Edition
Don Knowles

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Preface

Thanks to the support the *Today's Technician* series has received from those who teach automotive technology, Delmar Cengage Learning, the leader in automotive-related textbooks, is able to live up to its promise to regularly provide new editions of texts of this series. We have listened and responded to our critics and our fans and present this new updated and revised fifth edition. By revising this series on a regular basis, we can respond to changes in the industry, changes in technology, changes in the certification process, and to the ever-changing needs of those who teach automotive technology.

We also listened to instructors who said something was missing or incomplete in the last edition. We responded to those and the results are included in this fifth edition.

The *Today's Technician* series features textbooks that cover all mechanical and electrical systems of automobiles and light trucks. Principally, the individual titles correspond to the certification areas for 2009 in areas of National Institute for Automotive Service Excellence (ASE) certification.

Additional titles include remedial skills and theories common to all of the certification areas and advanced or specific subject areas that reflect the latest technological trends.

This new edition, like the last, was designed to give students a chance to develop the same skills and gain the same knowledge that today's successful technician has. This edition also reflects the changes in the guidelines established by the National Automotive Technicians Education Foundation (NATEF) in 2008.

The purpose of NATEF is to evaluate technician training programs against standards developed by the automotive industry and recommend qualifying programs for certification (accreditation) by ASE. Programs can earn ASE certification upon the recommendation of NATEF. NATEF's national standards reflect the skills that students must master. ASE certification through NATEF evaluation ensures that certified training programs meet or exceed industry-recognized, uniform standards of excellence.

The technician of today and for the future must know the underlying theory of all automotive systems and be able to service and maintain those systems. Dividing the material into two volumes, a Classroom Manual and a Shop Manual, provides the reader with the information needed to begin a successful career as an automotive technician without interrupting the learning process by mixing cognitive and performance learning objectives into one volume.

The design of Delmar's *Today's Technician* series was based on features that are known to promote improved student learning. The design was further enhanced by a careful study of survey results, in which the respondents were asked to value particular features. Some of these features can be found in other textbooks, while others are unique to this series.

Each Classroom Manual contains the principles of operation for each system and subsystem. The Classroom Manual also contains discussions on design variations of key components used by the different vehicle manufacturers. It also looks into emerging technologies that will be standard or optional features in the near future. This volume is organized to build upon basic facts and theories. The primary objective of this volume is to allow the reader to gain an understanding of how each system and subsystem operates. This understanding is necessary to diagnose the complex automobiles of today and tomorrow. Although the basics contained in the Classroom Manual provide the knowledge needed for diagnostics, diagnostic procedures appear only in the Shop Manual. An understanding of the underlying theories is also a requirement for competence in the skill areas covered in the Shop Manual.

A coil-ring-bound Shop Manual covers the "how-to's." This volume includes step-by-step instructions for diagnostic and repair procedures. Photo Sequences are used to illustrate some of the common service procedures. Other common procedures are listed and are accompanied with fine line drawings and photos that allow the reader to visualize and conceptualize the finest details of the procedure. This volume also contains the reasons for performing the procedures, as well as when that particular service is appropriate.

The two volumes are designed to be used together and are arranged in corresponding chapters. Not only are the chapters in the volumes linked together, the contents of the chapters are also linked. This linking of content is evidenced by marginal callouts that refer the reader to the chapter and page that the same topic is addressed in the other volume. This feature is valuable to instructors. Without this feature, users of other two-volume textbooks must search the index or table of contents to locate supporting information in the other volume. This is not only cumbersome but also creates additional work for an instructor when planning the presentation of material and when making reading assignments. It is also valuable to the students; with the page references, they also know exactly where to look for supportive information.

Both volumes contain clear and thoughtfully selected illustrations. Many of which are original drawings or photos specially prepared for inclusion in this series. This means that the art is a vital part of each textbook and not merely inserted to increase the number of illustrations.

The page layout, used in the series, is designed to include information that would otherwise break up the flow of information presented to the reader. The main body of the text includes all of the "need-to-know" information and illustrations. In the wide side margins of each page are many of the special features of the series. Items that are truly "nice-to-know" information such as: simple examples of concepts just introduced in the text, explanations or definitions of terms that are not defined in the text, examples of common trade jargon used to describe a part or operation, and exceptions to the norm explained in the text. This type of information is placed in the margin, out of the normal flow of information. Many textbooks attempt to include this type of information and insert it in the main body of text; this tends to interrupt the thought process and cannot be pedagogically justified. By placing this information off to the side of the main text, the reader can select when to refer to it.

Jack Erjavec
Series Editor

Highlights of this Edition—Classroom Manual

The text was updated to include the latest technology in suspension and steering systems. Some of these systems include hybrid vehicle steering systems, active steering systems, rear active steering (RAS), four-wheel active steering (4WAS) systems, data network systems, computer-controlled suspension systems, and adaptive cruise control systems. The text also includes the latest technology in vehicle stability control systems, traction control systems, active roll control, lane departure warning (LDW) systems, collision mitigation systems, telematics, and tire pressure monitoring systems (TPMS).

The first chapter explains the design and purpose of basic suspension and steering systems. This chapter provides students with the necessary basic understanding of suspension and steering systems. The other chapters in the book allow the student to build upon his or her understanding of these basic systems.

The second chapter explains all the basic theories required to understand the latest suspension and steering systems described in the other chapters. Students must understand these basic theories to comprehend the complex systems explained later in the text.

The other chapters in the book explain all the current model systems and components such as wheel bearings, tires and wheels, shock absorbers and struts, front and rear suspension systems, computer-controlled suspension systems, steering columns and linkages, power steering pumps, steering gears and systems, four-wheel steering systems, frames, and four-wheel alignment. Many art pieces have been replaced or updated throughout the text to improve visual concepts of suspension and steering systems and components.

HIGHLIGHTS OF THIS EDITION—SHOP MANUAL

The chapters in the Shop Manual have been updated to explain the diagnostic and service procedures for the latest systems and components described in the Classroom Manual. Diagnostics is a very important part of an automotive technician's job. Therefore, proper diagnostic procedures are emphasized in the Shop Manual.

A number of new Photo Sequences have been added in Chapters 3 through 16. These Photo Sequences illustrate the correct diagnostic or service procedure for a specific system or component. These Photo Sequences allow the students to visualize the diagnostic or service procedure. Visualization of these diagnostic and service procedures helps students to remember the procedures, and perform them more accurately and efficiently. The text covers the information required to pass a ASE test in Suspension and Steering Systems.

Chapter 1 explains the necessary safety precautions and procedures in an automotive repair shop. General shop safety and the required shop safety equipment are explained in the text. The text describes safety procedures when operating vehicles and various types of automotive service equipment. Correct procedures for handling hazardous waste materials are detailed in the text.

Chapter 2 describes suspension and steering diagnostic and service equipment and the use of service manuals. This chapter also explains employer and employee obligations and ASE certification requirements.

The other chapters in the text have been updated to explain the diagnostic and service procedures for the latest suspension and steering systems explained in the Classroom Manual. Some new job sheets related to the new systems and components have been added in the text. Many art pieces have been replaced or updated to improve the student's visualization of diagnostic and service procedures.

Don Knowles

CLASSROOM MANUAL

Features of the Classroom Manual include the following:


Chapter 1

SUSPENSION AND STEERING SYSTEMS

UPON COMPLETION AND REVIEW OF THIS CHAPTER, YOU SHOULD BE ABLE TO UNDERSTAND AND DESCRIBE:

- How strength and rigidity are designed into a unitized body.
- The advantages of reduced vehicle weight.
- The design of a short-and-long arm (SLA) front suspension system.
- How limited independent rear wheel movement is provided in a semi-independent rear suspension system.
- The advantage of an independent rear suspension system.
- The purposes of vehicle tires.
- The terms positive and negative offset as they relate to vehicle wheel rims.
- Three different loads that are applied to wheel bearings.
- The purposes of shock absorbers.
- The difference between a shock absorber and a strut.
- Two different types of computer-controlled shock absorbers.
- The advantages of computer-controlled suspension systems.
- Two types of steering linkages.
- How the rack is moved in a rack and pinion steering gear.
- How a power steering pump develops hydraulic pressure.
- The advantages of four-wheel steering.
- The result of incorrect rear wheel toe.
- Front wheel caster.
- The results of excessive negative camber.

INTRODUCTION

The suspension system must provi... these functions i... ...l and ride quality. Performing ...safety and customer satisfac... ...ertical wheel oscillations, the ...ular road surface. This loss of ...ury. Excessive vertical wheel ...he passenger compartment. ...heels and tires properly to ...ion system does not posi... ...correct and usually cause ...lso cause the steering to ...s and tires properly, the ...iven straight ahead on a

1

valves and orifices to provide enough friction to prevent the spring from overextending on the rebound stroke. These piston valves and orifices must not create excessive friction, which slows the wheel from returning to its original position.

Shock absorber pistons have many different types of valves and orifices. In some pistons, small orifices control the oil flow during slow wheel and suspension movements. Stacked steel valves control the oil flow during medium speed wheel and suspension movements. During maximum wheel and suspension movements, larger orifices between the piston valves provide oil flow control. On other shock absorber pistons, the stacked steel valves alone provide oil flow control. Regardless of the piston orifice and valve design, the shock absorber must be precisely matched to absorb the spring's energy.

During fast upward wheel movement on the compression stroke, excessive pressure in the lower oil chamber forces the base valve open and thus allows oil to flow through this valve to the reservoir. The nitrogen gas provides a compensating space for the oil that is displaced into the reservoir on the compression stroke and when the oil is heated. Since the gas exerts pressure on the oil, cavitation, or foaming of the oil, is eliminated. When oil bubbles are eliminated in this way, the shock absorber provides continuous damping for wheel deflections as small as 0.078 in (2.0 mm). A rebound rubber is located on top of the piston. If the wheel drops downward into a hole, the shock absorber may become fully extended. Under this condition, the rebound rubber provides a cushioning action.

Shop Manual Chapter 5, page 173

AUTHOR'S NOTE: Of all the suspension components, shock absorbers and struts contribute the most to ride quality. As the vehicle is driven over road irregularities, the shock absorbers or struts are continually operating to control the spring action and provide acceptable ride quality. It has been my experience that shock absorbers and struts usually wear out first in suspension systems, because they are working every time a wheel strikes a road irregularity. Therefore, you must understand not only shock absorber and strut operation but also how ride quality is affected if these components are not functioning properly. Thus, you must know shock absorber and strut diagnosis and service procedures.

GAS-FILLED SHOCK ABSORBERS AND STRUTS

Gas-filled units are identified with a warning label. If a **gas-filled shock absorber** is removed and compressed to its shortest length, it should re-extend when it is released. Failure to re-extend indicates that shock absorber or strut replacement is necessary.

A **gas-filled shock absorber** contains a nitrogen gas charge to maintain pressure on the oil in the shock.

WARNING: New gas-filled shock absorbers are wired in the compressed position for shipping purposes. Exercise caution when cutting this wire strap because shock absorber extension may cause personal injury. After the upper shock absorber attaching bolt is installed, the wire strap can be cut to allow the unit to extend. Front gas-filled struts have an internal catch that holds them in the compressed position. This catch is released when the strut rod is held and the strut rotated 45° counterclockwise.

CAUTION: When drilling worn-out shock absorbers or struts to relieve the gas pressure prior to disposal, drill the shock absorber only at the vehicle manufacturer's specified location.

WARNING: Do not throw gas-filled shock absorbers or struts in the fire or apply excessive heat or flame to these units. These procedures may cause the unit to explode, resulting in personal injury.

WARNING: Never apply heat to a shock absorber or strut chamber with an acetylene torch. This action may cause a shock absorber or strut explosion resulting in personal injury.

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SIDE

FIGURE 1-3 Engine cradle.

FIGURE 1-4 Rear partial frame.

Shop Manual Chapter 14, page 472

Carbon dioxide is a byproduct of the gasoline, diesel fuel, or ethanol combustion process.

A **greenhouse gas** is one that collects high in the earth's atmosphere and covers the earth like a blanket, due to which more heat is retained on the planet.

In the United States, it is estimated that automobiles contribute 1.5 billion tons of CO_2 to the atmosphere each year. Coal-burning power plants produce 2.5 billion tons of CO_2 each year.

The unitized body provides a steel box around the passenger compartment to provide passenger protection in a collision. In most unitized bodies, special steel panels are inserted in the doors to protect the vehicle occupants in a side collision. Some unitized body components are manufactured from high-strength or ultra high-strength steels. The unitized body design is typically used in small- and mid-sized front-wheel-drive cars. A steel cradle is mounted under the front of the unitized body to support the engine and transaxle (Figure 1-3). Rubber and steel mounts support the engine and transaxle on the cradle. Large rubber bushings are mounted between the cradle and the unitized body to help prevent engine vibration from reaching the passenger compartment. Some unitized bodies have a partial frame mounted under the rear of the vehicle to provide additional strength and facilitate the attachment of rear suspension components (Figure 1-4).

Vehicle weight plays a significant role in fuel consumption. One automotive design engineer states that "Fuel economy improvements are almost linear with weight reduction. A 30 percent reduction in vehicle weight provides approximately a 30 percent improvement in fuel economy." If a Toyota Prius weighs 3,300 lb (1,497 kg) and provides 50 miles per gallon (mpg), the same Prius would provide 55 mpg if it weighed 3,000 lb (1,360 kg).

Carbon dioxide (CO_2) emissions are a major concern for automotive manufacturers, because CO_2 is a **greenhouse gas** that contributes to global warming. Vehicle manufacturers are facing increasingly stringent CO_2 emission standards. CO_2 emissions are proportional to fuel consumption. Reduced fuel consumption results in lower CO_2 emissions. Therefore, reducing vehicle weight results in less fuel consumption and lower CO_2 emissions. Reduced weight also contributes to improved vehicle performance.

3

COGNITIVE OBJECTIVES

These objectives define the contents of the chapter and define what the student should have learned upon completion of the chapter.

Each topic is divided into small units to promote easier understanding and learning.

CAUTIONS AND WARNINGS

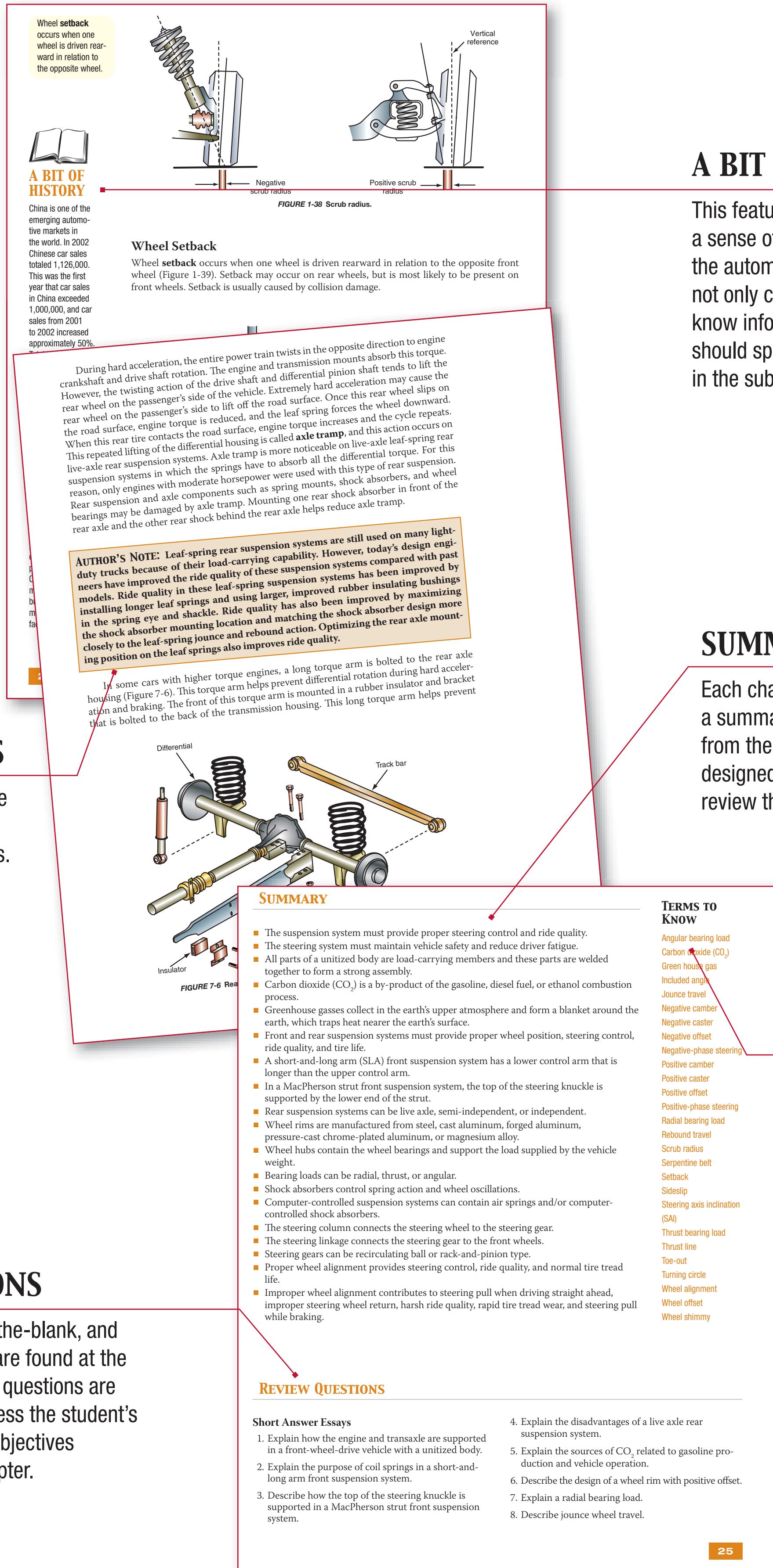
Throughout the text, warnings are given to alert the reader to potentially hazardous materials or unsafe conditions. Cautions are given to advise the student of things that can go wrong if instructions are not followed or if a nonacceptable part or tool is used.

CROSS-REFERENCES TO THE SHOP MANUAL

Reference to the appropriate page in the Shop Manual is given whenever necessary. Although the chapters of the two manuals are synchronized, material covered in other chapters of the Shop Manual may be fundamental to the topic discussed in the Classroom Manual.

MARGINAL NOTES

These notes add "nice-to-know" information to the discussion. They may include examples or exceptions, or may give the common trade jargon for a component.



Wheel **setback** occurs when one wheel is driven rearward in relation to the opposite wheel.

A BIT OF HISTORY

China is one of the emerging automotive markets in the world. In 2002 Chinese car sales totaled 1,126,000. This was the first year that car sales in China exceeded 1,000,000, and car sales from 2001 to 2002 increased approximately 50%.

FIGURE 1-38 Scrub radius.

Wheel Setback

Wheel **setback** occurs when one wheel is driven rearward in relation to the opposite front wheel (Figure 1-39). Setback may occur on rear wheels, but is most likely to be present on front wheels. Setback is usually caused by collision damage.

During hard acceleration, the entire power train twists in the opposite direction to engine crankshaft and drive shaft rotation. The engine and transmission mounts absorb this torque. However, the twisting action of the drive shaft and differential pinion shaft tends to lift the rear wheel on the passenger's side of the vehicle. Extremely hard acceleration may cause the rear wheel on the passenger's side to lift off the road surface. Once this rear wheel slips on the road surface, engine torque is reduced, and the leaf spring forces the wheel downward. When this rear tire contacts the road surface, engine torque increases and the cycle repeats. This repeated lifting of the differential housing is called **axle tramp**, and this action occurs on live-axle rear suspension systems. Axle tramp is more noticeable on live-axle leaf-spring rear suspension systems in which the springs have to absorb all the differential torque. For this reason, only engines with moderate horsepower were used with this type of rear suspension. Rear suspension and axle components such as spring mounts, shock absorbers, and wheel bearings may be damaged by axle tramp. Mounting one rear shock absorber in front of the rear axle and the other rear shock behind the rear axle helps reduce axle tramp.

AUTHOR'S NOTE: Leaf-spring rear suspension systems are still used on many light-duty trucks because of their load-carrying capability. However, today's design engineers have improved the ride quality of these suspension systems compared with past models. Ride quality in these leaf-spring suspension systems has been improved by installing longer leaf springs and using larger, improved rubber insulating bushings in the spring eye and shackle. Ride quality has also been improved by maximizing the shock absorber mounting location and matching the shock absorber design more closely to the leaf-spring jounce and rebound action. Optimizing the rear axle mounting position on the leaf springs also improves ride quality.

In some cars with higher torque engines, a long torque arm is bolted to the rear axle housing (Figure 7-6). This torque arm helps prevent differential rotation during hard acceleration and braking. The front of this torque arm is mounted in a rubber insulator and bracket that is bolted to the back of the transmission housing. This long torque arm helps prevent

FIGURE 7-6 Rea...

SUMMARY

- The suspension system must provide proper steering control and ride quality.
- The steering system must maintain vehicle safety and reduce driver fatigue.
- All parts of a unitized body are load-carrying members and these parts are welded together to form a strong assembly.
- Carbon dioxide (CO_2) is a by-product of the gasoline, diesel fuel, or ethanol combustion process.
- Greenhouse gasses collect in the earth's upper atmosphere and form a blanket around the earth, which traps heat nearer the earth's surface.
- Front and rear suspension systems must provide proper wheel position, steering control, ride quality, and tire life.
- A short-and-long arm (SLA) front suspension system has a lower control arm that is longer than the upper control arm.
- In a MacPherson strut front suspension system, the top of the steering knuckle is supported by the lower end of the strut.
- Rear suspension systems can be live axle, semi-independent, or independent.
- Wheel rims are manufactured from steel, cast aluminum, forged aluminum, pressure-cast chrome-plated aluminum, or magnesium alloy.
- Wheel hubs contain the wheel bearings and support the load supplied by the vehicle weight.
- Bearing loads can be radial, thrust, or angular.
- Shock absorbers control spring action and wheel oscillations.
- Computer-controlled suspension systems can contain air springs and/or computer-controlled shock absorbers.
- The steering column connects the steering wheel to the steering gear.
- The steering linkage connects the steering gear to the front wheels.
- Steering gears can be recirculating ball or rack-and-pinion type.
- Proper wheel alignment provides steering control, ride quality, and normal tire tread life.
- Improper wheel alignment contributes to steering pull when driving straight ahead, improper steering wheel return, harsh ride quality, rapid tire tread wear, and steering pull while braking.

TERMS TO KNOW

Angular bearing load
Carbon dioxide (CO_2)
Green house gas
Included angle
Jounce travel
Negative camber
Negative caster
Negative offset
Negative-phase steering
Positive camber
Positive caster
Positive offset
Positive-phase steering
Radial bearing load
Rebound travel
Scrub radius
Serpentine belt
Setback
Sideslip
Steering axis inclination (SAI)
Thrust bearing load
Thrust line
Toe-out
Turning circle
Wheel alignment
Wheel offset
Wheel shimmy

REVIEW QUESTIONS

Short Answer Essays

1. Explain how the engine and transaxle are supported in a front-wheel-drive vehicle with a unitized body.
2. Explain the purpose of coil springs in a short-and-long arm front suspension system.
3. Describe how the top of the steering knuckle is supported in a MacPherson strut front suspension system.
4. Explain the disadvantages of a live axle rear suspension system.
5. Explain the sources of CO_2 related to gasoline production and vehicle operation.
6. Describe the design of a wheel rim with positive offset.
7. Explain a radial bearing load.
8. Describe jounce wheel travel.

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A BIT OF HISTORY

This feature gives the student a sense of the evolution of the automobile. This feature not only contains nice-to-know information, but also should spark some interest in the subject matter.

SUMMARIES

Each chapter concludes with a summary of key points from the chapter. These are designed to help the reader review the chapter contents.

AUTHOR'S NOTES

This feature includes simple explanations, stories, or examples of complex topics. These are included to help students understand difficult concepts.

TERMS TO KNOW LIST

A list of new terms appears next to the Summary.

REVIEW QUESTIONS

Short answer essay, fill-in-the-blank, and multiple-choice questions are found at the end of each chapter. These questions are designed to accurately assess the student's competence in the stated objectives at the beginning of the chapter.

To stress the importance of safe work habits, the Shop Manual also dedicates one full chapter to safety. Other important features of this manual include:

PERFORMANCE-BASED OBJECTIVES

These objectives define the contents of the chapter and define what the student should have learned upon completion of the chapter. These objectives also correspond with the list of required tasks for NATEF certification. *Each NATEF task is addressed.*

Although this textbook is not designed to simply prepare someone for the certification exams, it is organized around the NATEF task list. These tasks are defined generically when the procedure is commonly followed and specifically when the procedure is unique for specific vehicle models. Imported and domestic model automobiles and light trucks are included in the procedures.

BASIC TOOLS LISTS

Each chapter begins with a list of the basic tools needed to perform the tasks included in the chapter.

MARGINAL NOTES

These notes add "nice-to-know" information to the discussion. They may include examples or exceptions, or may give the common trade jargon for a component.

SPECIAL TOOLS LISTS

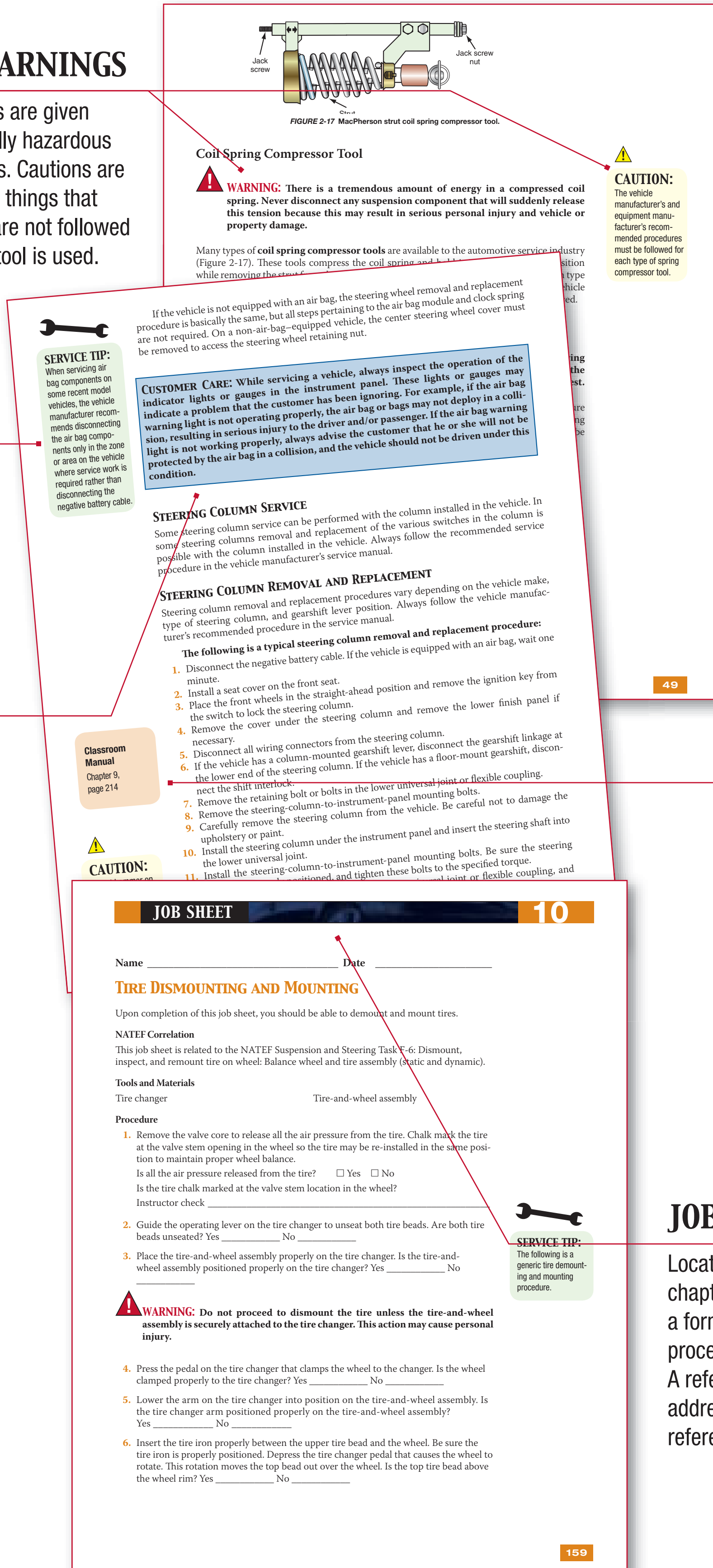
Whenever a special tool is required to complete a task, it is listed in the margin next to the procedure.

PHOTO SEQUENCES

Many procedures are illustrated in detailed Photo Sequences. These detailed photographs show the students what to expect when they perform particular procedures. They also can provide the student a familiarity with a system or type of equipment, which the school may not have.

CAUTIONS AND WARNINGS

Throughout the text, warnings are given to alert the reader to potentially hazardous materials or unsafe conditions. Cautions are given to advise the student of things that can go wrong if instructions are not followed or if a nonacceptable part or tool is used.



SERVICE TIPS

Whenever a short-cut or special procedure is appropriate, it is described in the text. These tips are generally those things commonly done by experienced technicians.

CUSTOMER CARE

This feature highlights those little things a technician can do or say to enhance customer relations.

CROSS-REFERENCES TO THE CLASSROOM MANUAL

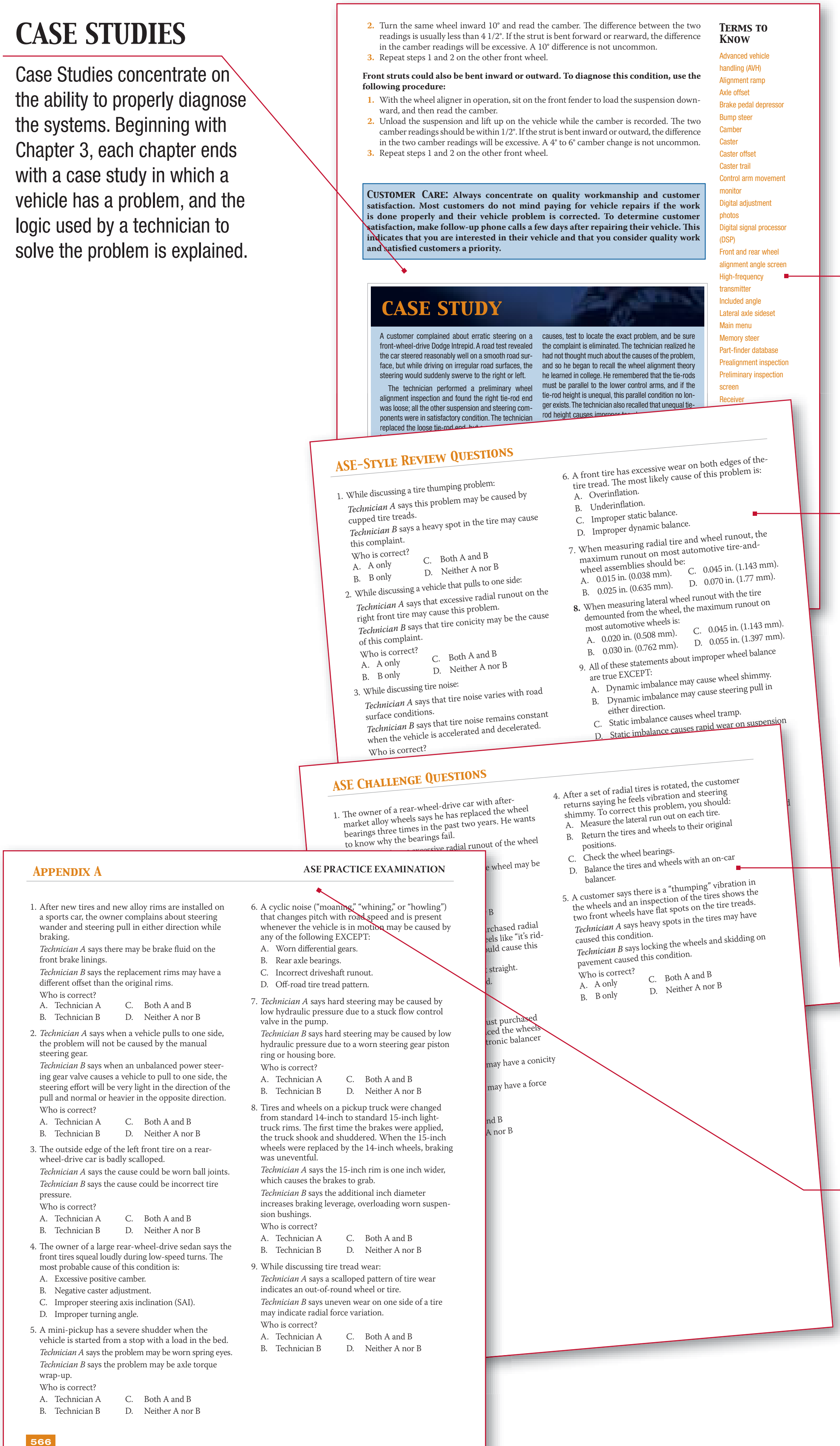
Reference to the appropriate page in the Classroom Manual is given whenever necessary. Although the chapters of the two manuals are synchronized, material covered in other chapters of the Classroom Manual may be fundamental to the topic discussed in the Shop Manual.

JOB SHEETS

Located at the end of each chapter, the Job Sheets provide a format for students to perform procedures covered in the chapter. A reference to the NATEF Task addressed by the procedure is referenced on the Job Sheet.

CASE STUDIES

Case Studies concentrate on the ability to properly diagnose the systems. Beginning with Chapter 3, each chapter ends with a case study in which a vehicle has a problem, and the logic used by a technician to solve the problem is explained.



TERMS TO KNOW LIST

Terms in this list can be found in the Glossary at the end of the manual.

ASE-STYLE REVIEW QUESTIONS

Each chapter contains ASE-style review questions that reflect the performance-based objectives listed at the beginning of the chapter. These questions can be used to review the chapter as well as to prepare for the ASE certification exam.

ASE CHALLENGE QUESTIONS

Each technical chapter ends with five ASE challenge challenge questions. These are not more review questions, rather they test the students' ability to apply general knowledge to the contents of the chapter.

ASE PRACTICE EXAMINATION

A 50 question ASE practice exam, located in the appendix, is included to test students on the contents of the Shop Manual.

Supplements

Instructor Resources

The Instructor Resources DVD is a robust ancillary that contains all preparation tools to meet any instructor's classroom needs. It includes presentations in PowerPoint with images, video clips and animations that coincide with each chapter's content coverage, a computerized test bank with hundreds of test questions, a searchable image library with all pictures from the text, theory-based worksheets in Word that provide homework or in-class assignments, the Job Sheets from the Shop Manual in Word, a NATEF correlation chart, and an Instructor's Guide in electronic format.

WebTutor Advantage

Newly available for this title and to the Today's Technician™ Series is the *WebTutor Advantage,* for Blackboard and Angel online course management systems. *The WebTutor for Today's Technician: Suspension & Steering Systems, 5e*, will include chapter presentations in PowerPoint with video clips and animations, end-of-chapter review questions, pretests and post-tests, worksheets, discussion springboard topics, an ASE Test Prep section, ASE Checklist, Job Sheets, and more. The *WebTutor* is designed to enhance the classroom and shop experience, engage students, and help them prepare for ASE certification exams.

Reviewers

The author and publisher would like to extend a special thanks to the instructors who reviewed this text and offered invaluable feedback:

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Contents

Photo Sequences

Job Sheets

Preface

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The *Today's Technician* series features textbooks that cover all mechanical and electrical systems of automobiles and light trucks. Principally, the individual titles correspond to the certification areas for 2009 in areas of National Institute for Automotive Service Excellence (ASE) certification.

Additional titles include remedial skills and theories common to all of the certification areas and advanced or specific subject areas that reflect the latest technological trends.

This new edition, like the last, was designed to give students a chance to develop the same skills and gain the same knowledge that today's successful technician has. This edition also reflects the changes in the guidelines established by the National Automotive Technicians Education Foundation (NATEF) in 2008.

The purpose of NATEF is to evaluate technician training programs against standards developed by the automotive industry and recommend qualifying programs for certification (accreditation) by ASE. Programs can earn ASE certification upon the recommendation of NATEF. NATEF's national standards reflect the skills that students must master. ASE certification through NATEF evaluation ensures that certified training programs meet or exceed industry-recognized, uniform standards of excellence.

The technician of today and for the future must know the underlying theory of all automotive systems and be able to service and maintain those systems. Dividing the material into two volumes, a Classroom Manual and a Shop Manual, provides the reader with the information needed to begin a successful career as an automotive technician without interrupting the learning process by mixing cognitive and performance learning objectives into one volume.

The design of Delmar's *Today's Technician* series was based on features that are known to promote improved student learning. The design was further enhanced by a careful study of survey results, in which the respondents were asked to value particular features. Some of these features can be found in other textbooks, while others are unique to this series.

Each Classroom Manual contains the principles of operation for each system and subsystem. The Classroom Manual also contains discussions on design variations of key components used by the different vehicle manufacturers. It also looks into emerging technologies that will be standard or optional features in the near future. This volume is organized to build upon basic facts and theories. The primary objective of this volume is to allow the reader to gain an understanding of how each system and subsystem operates. This understanding is necessary to diagnose the complex automobiles of today and tomorrow. Although the basics contained in the Classroom Manual provide the knowledge needed for diagnostics, diagnostic procedures appear only in the Shop Manual. An understanding of the underlying theories is also a requirement for competence in the skill areas covered in the Shop Manual.

A coil-ring-bound Shop Manual covers the "how-to's." This volume includes step-by-step instructions for diagnostic and repair procedures. Photo Sequences are used to illustrate some of the common service procedures. Other common procedures are listed and are accompanied with fine line drawings and photos that allow the reader to visualize and conceptualize the finest details of the procedure. This volume also contains the reasons for performing the procedures, as well as when that particular service is appropriate.

The two volumes are designed to be used together and are arranged in corresponding chapters. Not only are the chapters in the volumes linked together, the contents of the chapters are also linked. This linking of content is evidenced by marginal callouts that refer the reader to the chapter and page that the same topic is addressed in the other volume. This feature is valuable to instructors. Without this feature, users of other two-volume textbooks must search the index or table of contents to locate supporting information in the other volume. This is not only cumbersome but also creates additional work for an instructor when planning the presentation of material and when making reading assignments. It is also valuable to the students, with the page references they also know exactly where to look for supportive information.

Both volumes contain clear and thoughtfully selected illustrations. Many of which are original drawings or photos specially prepared for inclusion in this series. This means that the art is a vital part of each textbook and not merely inserted to increase the number of illustrations.

The page layout, used in the series, is designed to include information that would otherwise break up the flow of information presented to the reader. The main body of the text includes all of the "need-to-know" information and illustrations. In the wide side margins of each page are many of the special features of the series. Items that are truly "nice-to-know" information such as: simple examples of concepts just introduced in the text, explanations or definitions of terms that are not defined in the text, examples of common trade jargon used to describe a part or operation, and exceptions to the norm explained in the text. This type of information is placed in the margin, out of the normal flow of information. Many textbooks attempt to include this type of information and insert it in the main body of text; this tends to interrupt the thought process and cannot be pedagogically justified. By placing this information off to the side of the main text, the reader can select when to refer to it.

Jack Erjavec
Series Editor

Highlights of this Edition—Classroom Manual

The text was updated to include the latest technology in suspension and steering systems. Some of these systems include hybrid vehicle steering systems, active steering systems, rear active steering (RAS), four-wheel active steering (4WAS) systems, data network systems, computer-controlled suspension systems, and adaptive cruise control systems. The text also includes the latest technology in vehicle stability control systems, traction control systems, active roll control, lane departure warning (LDW) systems, collision mitigation systems, telematics, and tire pressure monitoring systems (TPMS).

The first chapter explains the design and purpose of basic suspension and steering systems. This chapter provides students with the necessary basic understanding of suspension and steering systems. The other chapters in the book allow the student to build upon his or her understanding of these basic systems.

The second chapter explains all the basic theories required to understand the latest suspension and steering systems described in the other chapters. Students must understand these basic theories to comprehend the complex systems explained later in the text.

The other chapters in the book explain all the current model systems and components such as wheel bearings, tires and wheels, shock absorbers and struts, front and rear suspension systems, computer-controlled suspension systems, steering columns and linkages, power steering pumps, steering gears and systems, four-wheel steering systems, frames, and four-wheel alignment. Many art pieces have been replaced or updated throughout the text to improve visual concepts of suspension and steering systems and components.

HIGHLIGHTS OF THIS EDITION—SHOP MANUAL

The chapters in the Shop Manual have been updated to explain the diagnostic and service procedures for the latest systems and components described in the Classroom Manual. Diagnostics is a very important part of an automotive technician's job. Therefore, proper diagnostic procedures are emphasized in the Shop Manual.

A number of new Photo Sequences have been added in Chapters 3 through 16. These Photo Sequences illustrate the correct diagnostic or service procedure for a specific system or component. These Photo Sequences allow the students to visualize the diagnostic or service procedure. Visualization of these diagnostic and service procedures helps students to remember the procedures, and perform them more accurately and efficiently. The text covers the information required to pass a ASE test in Suspension and Steering Systems.

Chapter 1 explains the necessary safety precautions and procedures in an automotive repair shop. General shop safety and the required shop safety equipment are explained in the text. The text describes safety procedures when operating vehicles and various types of automotive service equipment. Correct procedures for handling hazardous waste materials are detailed in the text.

Chapter 2 describes suspension and steering diagnostic and service equipment and the use of service manuals. This chapter also explains employer and employee obligations, and ASE certification requirements.

The other chapters in the text have been updated to explain the diagnostic and service procedures for the latest suspension and steering systems explained in the Classroom Manual. Some new job sheets related to the new systems and components have been added in the text. Many art pieces have been replaced or updated to improve the student's visualization of diagnostic and service procedures.

Don Knowles

Classroom Manual

Features of this manual include the following:

COGNITIVE OBJECTIVES

These objectives define the contents of the chapter and define what the student should have learned upon completion of the chapter.

Each topic is divided into small units to promote easier understanding and learning.

Chapter 7

REAR SUSPENSION SYSTEMS

UPON COMPLETION AND REVIEW OF THIS CHAPTER, YOU SHOULD BE ABLE TO UNDERSTAND AND DESCRIBE:

- A live-axle rear suspension system.
- The advantages and disadvantages of a live-axle leaf-spring rear suspension system.
- The movement of the rear axle housing during vehicle acceleration.
- How the differential torque is absorbed in a live-axle coil-spring rear suspension system.
- The purpose of a tracking bar in a live-axle coil-spring rear suspension system.
- The difference between a semi-independent and an independent rear suspension system.
- How individual rear wheel movement is provided in a semi-independent rear suspension system.
- The difference between a MacPherson strut and a modified MacPherson strut rear suspension.
- The advantage of attaching the differential housing to the chassis in an independent rear suspension system.
- How differential and suspension vibration, noise, and shock are insulated from the chassis in a multilink independent rear suspension system.
- How the top of the knuckle is supported in a multilink independent rear suspension system.
- The effect of sagged rear springs on caster angle and steering.

INTRODUCTION

A **rear suspension system** with two longitudinal leaf springs and a one-piece rear axle ...

The **rear suspension system** plays a very important part in ride quality and in the control of suspension and differenti... steer the ... ration, and shock. Although the front wheels actually ... s also vital to steering control. The rear suspension ... maintain tire traction on the road surface. Rear sus... ter include live-axle, semi-independent, and inde... **tems** are found on rear-wheel-drive (RWD) trucks ... -wheel-drive (4WD) cars. Most front-wheel-drive ... independent rear suspensions. Independent rear ... nd 4WD cars.

...STEMS

...ach side of the rear suspension on some rear-... e relatively flat springs provide excellent lateral ... ute to a well-controlled ride with very good

A **pyrotechnic** device contains an explosive and an ignition source.

An **air bag deployment module** contains the air bag and the inflator device.

CAUTION: When servicing a vehicle equipped with an air bag or bags, follow all service precautions in the vehicle manufacturer's service manual. Failure to follow these precautions may result in an expensive, accidental air bag deployment.

The clock spring maintains positive electrical contact ...

required, the RCM fires a **pyrotechnic** device in the steering column that pulls a pin in the column and allows the energy-absorbing steel to buckle and provide faster column collapse. The result is a softer impact between the driver and the steering wheel. The adaptive steering column is designed to operate with the driver's air bag.

When the driver is thrown against the steering wheel during a collision, many steering wheels are designed to deform away from the driver to reduce the force on the driver's body.

WARNING: Small amounts of sodium hydroxide are a by-product of an air bag deployment. Sodium hydroxide is a caustic chemical that causes skin irritation and eye damage. Always wear eye protection and gloves when servicing and handling a deployed air bag.

On many cars, the **air bag deployment module** is mounted in the top of the steering wheel (Figure 9-6). A **clock spring electrical connector**, or **spiral cable**, is mounted under the steering wheel. This component contains a ribbon-type conductor that maintains constant electrical contact between the air bag module and the air bag electrical system during steering wheel rotation.

The steering wheel splines fit on matching splines on the top of the upper steering shaft, and a nut retains the wheel on the shaft. Most steering wheels and shafts have matching alignment marks that must be aligned when the steering wheel is installed.

An ignition switch cylinder is usually mounted in the upper right side of the column housing, and the ignition switch is bolted on the lower side of the housing (Figure 9-7). An operating rod connects the ignition switch cylinder to the ignition switch. Ignition switches are integral with the lock cylinder in some steering columns.

The turn signal switch and hazard warning switch are mounted on top of the steering column under the steering wheel. Lugs on the bottom of the steering wheel are used to cancel the signal lights after a turn is completed. On many vehicles, the signal light lever also operates the wipe/wash switch and the dimmer switch (Figure 9-8).

If the gear shift is mounted in the steering column, a tube extends from the gear shift housing to the shift lever at the lower end of the steering column. This shift lever is connected through a linkage to the transaxle or transmission shift lever. A lock plate is attached to the upper steering shaft, and a lever engages the slots in this plate to lock the steering wheel and gear shift when ... in Park and the ignition switch is in the Lock position (Figure 9-9).

CAUTIONS AND WARNINGS

Throughout the text, warnings are given to alert the reader to potentially hazardous materials or unsafe conditions. Cautions are given to advise the student of things that can go wrong if instructions are not followed or if a nonacceptable part or tool is used.

CROSS-REFERENCES TO THE SHOP MANUAL

Reference to the appropriate page in the Shop Manual is given whenever necessary. Although the chapters of the two manuals are synchronized, material covered in other chapters of the Shop Manual may be fundamental to the topic discussed in the Classroom Manual.

supported by aluminum extrusions. This design allows the steering column, knee bolster, and pedals to move along the trajectory of the driver during a severe vehicle crash. This action helps to maintain air bag position. The driver protection module will be introduced on some 2009 vehicles, and some final design changes may be incorporated in the module. During a vehicle crash, the driver protection module movement may be controlled actively by a pyrotechnic device operated by an electronic module. The driver protection module will provide adequate crash protection for drivers from the 5th percentile to the 95th percentile. It is expected that this level of protection will be required by federal legislation in the future.

STEERING LINKAGE MECHANISMS

Parallelogram Steering Linkage

Shop Manual Chapter 9, page 313

A **parallelogram steering linkage** may be defined as one in which the tie-rods are mounted parallel to the lower control arms.

Steering linkage mechanisms are used to connect the steering gear to the front wheels. A **parallelogram steering linkage** may be mounted behind the front suspension (Figure 9-19) or in front of the front suspension (Figure 9-20). The parallelogram steering linkage must not interfere with the engine oil pan or chassis components.

WARNING: Always remember that a customer's life may depend on the condition of the steering linkages on his or her vehicle. State safety inspections play a very important role in maintaining suspension, steering, and other vehicle systems in safe driving condition and saving lives. During undercar service, always make a quick check of the steering linkage condition.

Regardless of the parallelogram steering linkage mounting position, this type of steering linkage contains the same components. The main components in this steering linkage mechanism are:

1. Pitman arm
2. Center link
3. Idler arm assembly
4. Tie-rods with sockets
5. Tie-rod ends

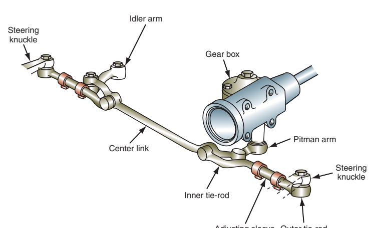

FIGURE 9-19 Parallelogram steering linkage behind the front suspension.

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MARGINAL NOTES

These notes add "nice-to-know" information to the discussion. They may include examples or exceptions, or may give the common trade jargon for a component.

FIGURE 15-9 Four wheel alignment with the thrust line adjusted so it is at the geometric centerline and the front wheel toe is referenced to the geometric centerline.

The advantages of four-wheel alignment are the following:

1. *Improved fuel mileage.* After a four-wheel alignment, all four wheels are parallel, and this condition combined with proper tire inflation decreases rolling resistance, which improves fuel mileage.
2. *Longer tire life.* When all four wheels are aligned properly, tire tread wear is minimized.
3. *Improved vehicle handling.* When all four wheels are properly aligned and all steering and suspension components are in satisfactory condition, steering pulls, vibrations, and abnormal steering conditions are eliminated to ensure improved vehicle handling.
4. *Safer driving.* Proper alignment of all four wheels plus inspection and replacement of all worn or defective steering and suspension components improves vehicle handling, and this reduces the possibility of a collision and provides safer driving.

COMPUTER ALIGNMENT SYSTEMS

Computer Wheel Aligner Features

Some computer wheel aligners have four high-resolution digital cameras that measure wheel target position and orientation. The front and rear wheel alignment angles are sensed by the digital cameras and wheel targets and then displayed on the wheel alignment monitor. The vehicle is raised to a comfortable working height on the aligner lift, and two digital cameras are mounted in each end of a crossbar on a post in front of the vehicle (Figure 15-10). The post and crossbar height may be adjusted to match the vehicle height.

FIGURE 15-10 Computer wheel aligner with digital cameras and wheel targets.

A BIT OF HISTORY

Early attempts at rear wheel alignment were slow and lacked precision. These attempts at rear wheel alignment included the use of a track bar and even backing the rear wheels of a car onto a front wheel aligner to align the rear wheels. To meet the need for fast, accurate front and rear wheel alignment, wheel alignment manufacturers designed computer wheel aligners. The technology in this equipment has greatly improved since the first models were introduced.

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side of the vehicle to provide directional...

TYPES OF FRAME DAMAGE

Side Sway

AUTHOR'S NOTE: It has been my experience that frame damage is most commonly caused by abuse, and this problem is usually encountered on light-duty trucks or sport utility vehicles (SUVs). The frame damage may occur when the vehicle is overloaded and/or driven abusively on extremely rough terrain. Another common cause of frame damage is from a vehicle collision. In this case, the frame damage was likely ignored or overlooked during the body repairs. Regardless of the cause, frame damage usually results in excessive tire tread wear and steering complaints.

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Shop Manual
Chapter 9, page 320

When a front wheel strikes a road irregularity, a shock is transferred from the front wheel to the steering linkage, steering gear, and steering wheel. The steering damper helps absorb this road shock and prevent it from reaching the steering wheel. Heavy-duty steering dampers are available for severe road conditions such as those sometimes encountered by four-wheel-drive vehicles.

TERMS TO KNOW

Air bag deployment module
Center link
Clock spring electrical connector
Energy-absorbing lower bracket
Idler arm
Parallelogram steering linkages
Pitman arm
Pre-safe system
Pyrotechnic
Rack and pinion steering linkage
Silencer
Spherical bearing
Spiral cable
Tie-rod
Toe plate

SUMMARY

- Steering columns help provide steering control, driver convenience, and driver safety.
- Many steering columns provide some method of energy absorption to protect the driver during a frontal collision.
- Steering wheels and columns now contain an air bag deployment module to protect the driver in a frontal collision.
- Tilt steering columns increase driver comfort and ease while driving or getting in or out of the driver's seat.
- A clock spring electrical connector supplies positive electrical contact between the air bag module in the steering wheel and the air bag electrical system.
- The ignition switch, dimmer switch, signal light switch, hazard switch, and wipe/wash switch may be mounted in the steering column.
- When the ignition switch is in the Lock position, a locking plate and lever in the upper steering column locks the steering wheel and the gear shift.
- In some tilt steering columns, the upper column housing pivots on two bolts, and the upper steering shaft pivots on a universal joint.
- In a parallelogram steering linkage, the tie-rods are parallel to the lower control arms.
- The parallelogram steering linkage minimizes toe change as the control arms move up and down on road irregularities.
- A rack and pinion steering linkage has reduced friction points; it is lightweight and compact compared with a parallelogram steering linkage.

REVIEW QUESTIONS

Short Answer Essays

1. Explain how a collapsible steering column protects the driver in a frontal collision.
2. Explain how the driver's side air bag protects the driver in a frontal collision.
3. Describe the purpose of a clock spring.
4. List the switches commonly found in a steering column.
5. Describe the type of mechanism used to lock the steering wheel and gear shift when the ignition is in the Lock position.
6. Describe the pivot points in the upper shaft and upper column tube in a tilt steering wheel.
7. List the wear points in a parallelogram steering linkage.
8. List the five main components in a parallelogram steering linkage, and explain the purpose of each component.
9. Describe the basic design of a rack and pinion steering linkage.
10. Explain the advantages of a rack and pinion steering linkage compared with a parallelogram steering linkage.

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A BIT OF HISTORY

This feature gives the student a sense of the evolution of the automobile. This feature not only contains nice-to-know information, but also should spark some interest in the subject matter.

AUTHOR'S NOTES

This feature includes simple explanations, stories, or examples of complex topics. These are included to help students understand difficult concepts.

SUMMARIES

Each chapter concludes with a summary of key points from the chapter. These are designed to help the reader review the chapter contents.

TERMS TO KNOW LIST

A list of new terms appears next to the Summary.

REVIEW QUESTIONS

Short answer essay, fill-in-the-blank, and multiple-choice questions are found at the end of each chapter. These questions are designed to accurately assess the student's competence in the stated objectives at the beginning of the chapter.

Shop Manual

To stress the importance of safe work habits, the Shop Manual also dedicates one full chapter to safety. Other important features of this manual include:

PERFORMANCE-BASED OBJECTIVES

These objectives define the contents of the chapter and define what the student should have learned upon completion of the chapter. These objectives also correspond with the list of required tasks for NATEF certification. *Each NATEF task is addressed.*

Although this textbook is not designed to simply prepare someone for the certification exams, it is organized around the NATEF task list. These tasks are defined generically when the procedure is commonly followed and specifically when the procedure is unique for specific vehicle models. Imported and domestic model automobiles and light trucks are included in the procedures.

BASIC TOOLS LISTS

Each chapter begins with a list of the basic tools needed to perform the tasks included in the chapter.

MARGINAL NOTES

These notes add “nice-to-know” information to the discussion. They may include examples or exceptions, or may give the common trade jargon for a component.

SERVICE TIPS

Whenever a short-cut or special procedure is appropriate, it is described in the text. These tips are generally those things commonly done by experienced technicians.

SPECIAL TOOLS LISTS

Whenever a special tool is required to complete a task, it is listed in the margin next to the procedure.

PHOTO SEQUENCES

Many procedures are illustrated in detailed Photo Sequences. These detailed photographs show the students what to expect when they perform particular procedures. They also can provide the student a familiarity with a system or type of equipment, which the school may not have.

CAUTIONS AND WARNINGS

Throughout the text, warnings are given to alert the reader to potentially hazardous materials or unsafe conditions. Cautions are given to advise the student of things that can go wrong if instructions are not followed or if a nonacceptable part or tool is used.

CUSTOMER CARE

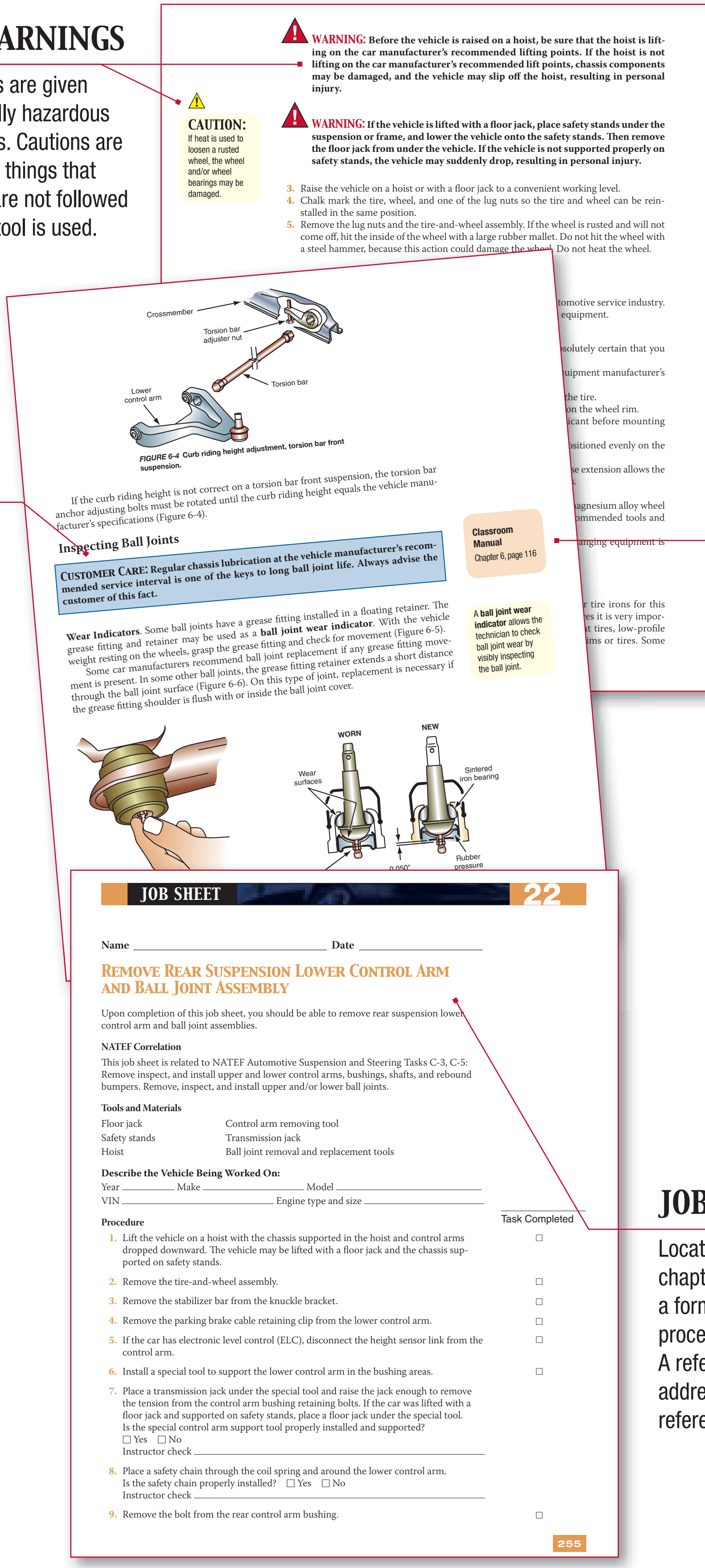
This feature highlights those little things a technician can do or say to enhance customer relations.

CROSS-REFERENCES TO THE CLASSROOM MANUAL

Reference to the appropriate page in the Classroom Manual is given whenever necessary. Although the chapters of the two manuals are synchronized, material covered in other chapters of the Classroom Manual may be fundamental to the topic discussed in the Shop Manual.

JOB SHEETS

Located at the end of each chapter, the Job Sheets provide a format for students to perform procedures covered in the chapter. A reference to the NATEF Task addressed by the procedure is referenced on the Job Sheet.



WARNING: Before the vehicle is raised on a hoist, be sure that the hoist is lifting on the car manufacturer's recommended lifting points. If the hoist is not lifting on the car manufacturer's recommended lift points, chassis components may be damaged, and the vehicle may slip off the hoist, resulting in personal injury.

CAUTION: If heat is used to loosen a rusted wheel, the wheel and/or wheel bearings may be damaged.

WARNING: If the vehicle is lifted with a floor jack, place safety stands under the suspension or frame, and lower the vehicle onto the safety stands. Then remove the floor jack from under the vehicle. If the vehicle is not supported properly on safety stands, the vehicle may suddenly drop, resulting in personal injury.

3. Raise the vehicle on a hoist or with a floor jack to a convenient working level.
4. Chalk mark the tire, wheel, and one of the lug nuts so the tire and wheel can be reinstalled in the same position.
5. Remove the lug nuts and the tire-and-wheel assembly. If the wheel is rusted and will not come off, hit the inside of the wheel with a large rubber mallet. Do not hit the wheel with a steel hammer, because this action could damage the wheel. Do not heat the wheel.

FIGURE 6-4 Curb riding height adjustment, torsion bar front suspension.

If the curb riding height is not correct on a torsion bar front suspension, the torsion bar anchor adjusting bolts must be rotated until the curb riding height equals the vehicle manufacturer's specifications (Figure 6-4).

Inspecting Ball Joints

CUSTOMER CARE: Regular chassis lubrication at the vehicle manufacturer's recommended service interval is one of the keys to long ball joint life. Always advise the customer of this fact.

Classroom Manual
Chapter 6, page 116

Wear Indicators. Some ball joints have a grease fitting installed in a floating retainer. The grease fitting and retainer may be used as a **ball joint wear indicator**. With the vehicle weight resting on the wheels, grasp the grease fitting and check for movement (Figure 6-5). Some car manufacturers recommend ball joint replacement if any grease fitting movement is present. In some other ball joints, the grease fitting retainer extends a short distance through the ball joint surface (Figure 6-6). On this type of joint, replacement is necessary if the grease fitting shoulder is flush with or inside the ball joint cover.

A ball joint wear indicator allows the technician to check ball joint wear by visibly inspecting the ball joint.

JOB SHEET 22

Name ______________ Date ______________

REMOVE REAR SUSPENSION LOWER CONTROL ARM AND BALL JOINT ASSEMBLY

Upon completion of this job sheet, you should be able to remove rear suspension lower control arm and ball joint assemblies.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Tasks C-3, C-5: Remove inspect, and install upper and lower control arms, bushings, shafts, and rebound bumpers. Remove, inspect, and install upper and/or lower ball joints.

Tools and Materials

Floor jack	Control arm removing tool
Safety stands	Transmission jack
Hoist	Ball joint removal and replacement tools

Describe the Vehicle Being Worked On:

Year ______ Make ______________ Model ______________

VIN ______________ Engine type and size ______________

Procedure Task Completed

1. Lift the vehicle on a hoist with the chassis supported in the hoist and control arms dropped downward. The vehicle may be lifted with a floor jack and the chassis supported on safety stands. ☐
2. Remove the tire-and-wheel assembly. ☐
3. Remove the stabilizer bar from the knuckle bracket. ☐
4. Remove the parking brake cable retaining clip from the lower control arm. ☐
5. If the car has electronic level control (ELC), disconnect the height sensor link from the control arm. ☐
6. Install a special tool to support the lower control arm in the bushing areas. ☐
7. Place a transmission jack under the special tool and raise the jack enough to remove the tension from the control arm bushing retaining bolts. If the car was lifted with a floor jack and supported on safety stands, place a floor jack under the special tool. Is the special control arm support tool properly installed and supported? ☐ Yes ☐ No
Instructor check ______________
8. Place a safety chain through the coil spring and around the lower control arm. Is the safety chain properly installed? ☐ Yes ☐ No
Instructor check ______________
9. Remove the bolt from the rear control arm bushing. ☐

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CASE STUDIES

Case Studies concentrate on the ability to properly diagnose the systems. Beginning with Chapter 3, each chapter ends with a case study in which a vehicle has a problem, and the logic used by a technician to solve the problem is explained.

TERMS TO KNOW LIST

Terms in this list can be found in the Glossary at the end of the manual.

ASE-STYLE REVIEW QUESTIONS

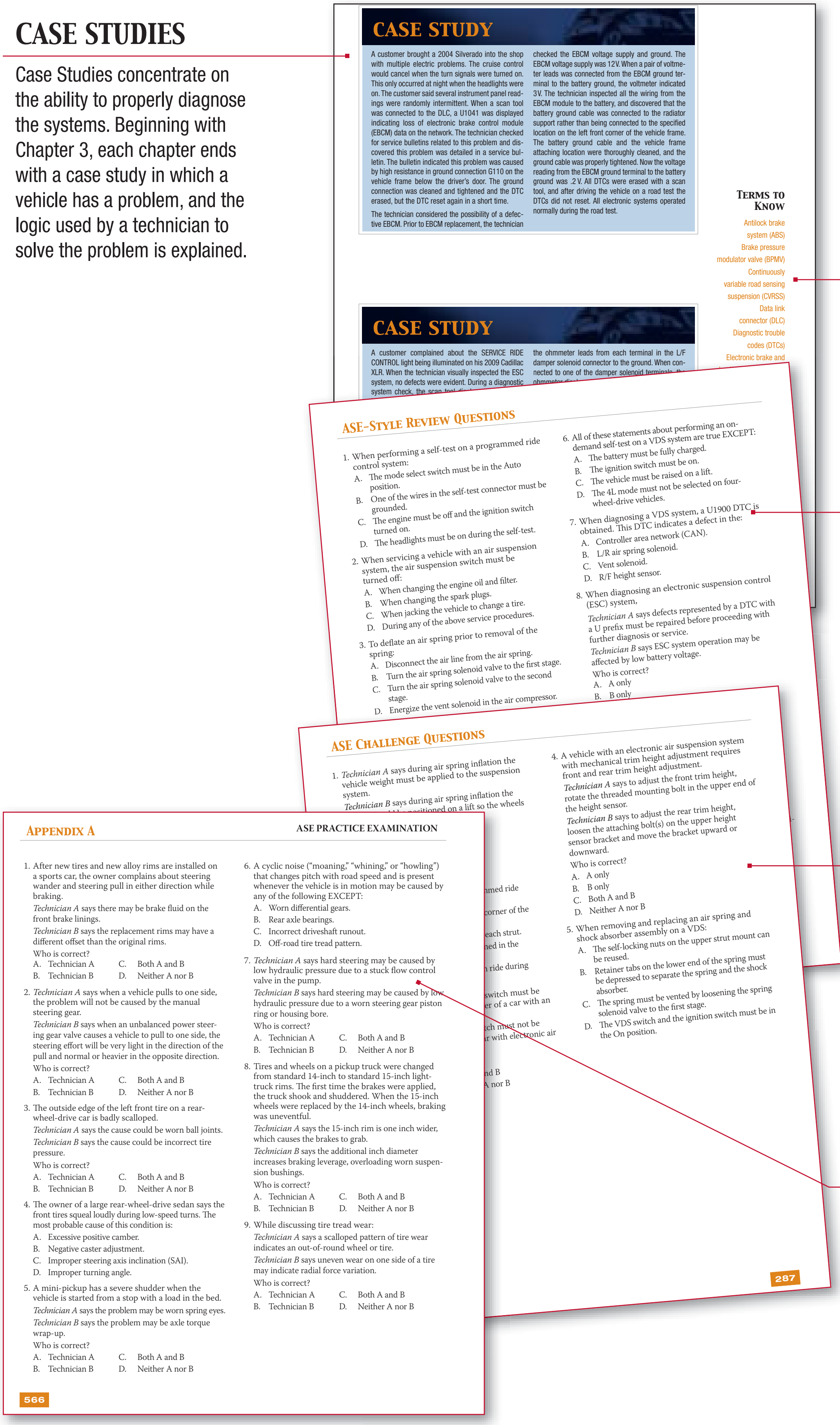
Each chapter contains ASE-style review questions that reflect the performance-based objectives listed at the beginning of the chapter. These questions can be used to review the chapter as well as to prepare for the ASE certification exam.

ASE CHALLENGE QUESTIONS

Each technical chapter ends with five ASE challenge challenge questions. These are not more review questions, rather they test the students' ability to apply general knowledge to the contents of the chapter.

ASE PRACTICE EXAMINATION

A 50-question ASE practice exam, located in the appendix, is included to test students on the contents of the Shop Manual.



CASE STUDY

A customer brought a 2004 Silverado into the shop with multiple electric problems. The cruise control would cancel when the turn signals were turned on. This only occurred at night when the headlights were on. The customer said several instrument panel readings were randomly intermittent. When a scan tool was connected to the DLC, a U1041 was displayed indicating loss of electronic brake control module (EBCM) data on the network. The technician checked for service bulletins related to this problem and discovered this problem was detailed in a service bulletin. The bulletin indicated this problem was caused by high resistance in ground connection G110 on the vehicle frame below the driver's door. The ground connection was cleaned and tightened and the DTC erased, but the DTC reset again in a short time.

The technician considered the possibility of a defective EBCM. Prior to EBCM replacement, the technician checked the EBCM voltage supply and ground. The EBCM voltage supply was 12V. When a pair of voltmeter leads was connected from the EBCM ground terminal to the battery ground, the voltmeter indicated 3V. The technician inspected all the wiring from the EBCM module to the battery, and discovered that the battery ground cable was connected to the radiator support rather than being connected to the specified location on the left front corner of the vehicle frame. The battery ground cable and the vehicle frame attaching location were thoroughly cleaned, and the ground cable was properly tightened. Now the voltage reading from the EBCM ground terminal to the battery ground was .2 V. All DTCs were erased with a scan tool, and after driving the vehicle on a road test the DTCs did not reset. All electronic systems operated normally during the road test.

TERMS TO KNOW

Antilock brake system (ABS)
Brake pressure modulator valve (BPMV)
Continuously variable road sensing suspension (CVRSS)
Data link connector (DLC)
Diagnostic trouble codes (DTCs)
Electronic brake and

CASE STUDY

A customer complained about the SERVICE RIDE CONTROL light being illuminated on his 2009 Cadillac XLR. When the technician visually inspected the ESC system, no defects were evident. During a diagnostic system check, the scan tool

the ohmmeter leads from each terminal in the L/F damper solenoid connector to the ground. When connected to one of the damper solenoid terminals, the

ASE-STYLE REVIEW QUESTIONS

1. When performing a self-test on a programmed ride control system:
   A. The mode select switch must be in the Auto position.
   B. One of the wires in the self-test connector must be grounded.
   C. The engine must be off and the ignition switch turned on.
   D. The headlights must be on during the self-test.
2. When servicing a vehicle with an air suspension system, the air suspension switch must be turned off:
   A. When changing the engine oil and filter.
   B. When changing the spark plugs.
   C. When jacking the vehicle to change a tire.
   D. During any of the above service procedures.
3. To deflate an air spring prior to removal of the spring:
   A. Disconnect the air line from the air spring.
   B. Turn the air spring solenoid valve to the first stage.
   C. Turn the air spring solenoid valve to the second stage.
   D. Energize the vent solenoid in the air compressor.
6. All of these statements about performing an on-demand self-test on a VDS system are true EXCEPT:
   A. The battery must be fully charged.
   B. The ignition switch must be on.
   C. The vehicle must be raised on a lift.
   D. The 4L mode must not be selected on four-wheel-drive vehicles.
7. When diagnosing a VDS system, a U1900 DTC is obtained. This DTC indicates a defect in the:
   A. Controller area network (CAN).
   B. L/R air spring solenoid.
   C. Vent solenoid.
   D. R/F height sensor.
8. When diagnosing an electronic suspension control (ESC) system,
   Technician A says defects represented by a DTC with a U prefix must be repaired before proceeding with further diagnosis or service.
   Technician B says ESC system operation may be affected by low battery voltage.
   Who is correct?
   A. A only
   B. B only

ASE CHALLENGE QUESTIONS

1. *Technician A* says during air spring inflation the vehicle weight must be applied to the suspension system.
   Technician B says during air spring inflation the wheels

4. A vehicle with an electronic air suspension system with mechanical trim height adjustment requires front and rear trim height adjustment.
   Technician A says to adjust the front trim height, rotate the threaded mounting bolt in the upper end of the height sensor.
   Technician B says to adjust the rear trim height, loosen the attaching bolt(s) on the upper height sensor bracket and move the bracket upward or downward.
   Who is correct?
   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B
5. When removing and replacing an air spring and shock absorber assembly on a VDS:
   A. The self-locking nuts on the upper strut mount can be reused.
   B. Retainer tabs on the lower end of the spring must be depressed to separate the spring and the shock absorber.
   C. The spring must be vented by loosening the spring solenoid valve to the first stage.
   D. The VDS switch and the ignition switch must be in the On position.

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APPENDIX A — ASE PRACTICE EXAMINATION

1. After new tires and new alloy rims are installed on a sports car, the owner complains about steering wander and steering pull in either direction while braking.
   Technician A says there may be brake fluid on the front brake linings.
   Technician B says the replacement rims may have a different offset than the original rims.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B
2. *Technician A* says when a vehicle pulls to one side, the problem will not be caused by the manual steering gear.
   Technician B says when an unbalanced power steering gear valve causes a vehicle to pull to one side, the steering effort will be very light in the direction of the pull and normal or heavier in the opposite direction.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B
3. The outside edge of the left front tire on a rear-wheel-drive car is badly scalloped.
   Technician A says the cause could be worn ball joints.
   Technician B says the cause could be incorrect tire pressure.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B
4. The owner of a large rear-wheel-drive sedan says the front tires squeal loudly during low-speed turns. The most probable cause of this condition is:
   A. Excessive positive camber.
   B. Negative caster adjustment.
   C. Improper steering axis inclination (SAI).
   D. Improper turning angle.
5. A mini-pickup has a severe shudder when the vehicle is started from a stop with a load in the bed.
   Technician A says the problem may be worn spring eyes.
   Technician B says the problem may be axle torque wrap-up.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B
6. A cyclic noise ("moaning," "whining," or "howling") that changes pitch with road speed and is present whenever the vehicle is in motion may be caused by any of the following EXCEPT:
   A. Worn differential gears.
   B. Rear axle bearings.
   C. Incorrect driveshaft runout.
   D. Off-road tire tread pattern.
7. *Technician A* says hard steering may be caused by low hydraulic pressure due to a stuck flow control valve in the pump.
   Technician B says hard steering may be caused by low hydraulic pressure due to a worn steering gear piston ring or housing bore.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B
8. Tires and wheels on a pickup truck were changed from standard 14-inch to standard 15-inch light-truck rims. The first time the brakes were applied, the truck shook and shuddered. When the 15-inch wheels were replaced by the 14-inch wheels, braking was uneventful.
   Technician A says the 15-inch rim is one inch wider, which causes the brakes to grab.
   Technician B says the additional inch diameter increases braking leverage, overloading worn suspension bushings.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B
9. While discussing tire tread wear:
   Technician A says a scalloped pattern of tire wear indicates an out-of-round wheel or tire.
   Technician B says uneven wear on one side of a tire may indicate radial force variation.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

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Supplements

Instructor Resources

The Instructor Resources DVD is a robust ancillary that contains all preparation tools to meet any instructor's classroom needs. It includes presentations in PowerPoint with images, video clips, and animations that coincide with each chapter's content coverage, a computerized test bank with hundreds of test questions, a searchable image library with all pictures from the text, theory-based worksheets in Word that provide homework or in-class assignments, the Job Sheets from the Shop Manual in Word, a NATEF correlation chart, and an Instructor's Guide in electronic format.

WebTutor Advantage

Newly available for this title and to the Today's Technician™ Series is the *WebTutor Advantage,* for Blackboard and Angel online course management systems. The *WebTutor for Today's Technician: Suspension & Steering Systems, 5e*, will include chapter presentations in PowerPoint with video clips and animations, end-of-chapter review questions, pretests and post-tests, worksheets, discussion springboard topics, an ASE Test Prep section, ASE Checklist, Job Sheets, and more. The *WebTutor* is designed to enhance the classroom and shop experience, engage students, and help them prepare for ASE certification exams.

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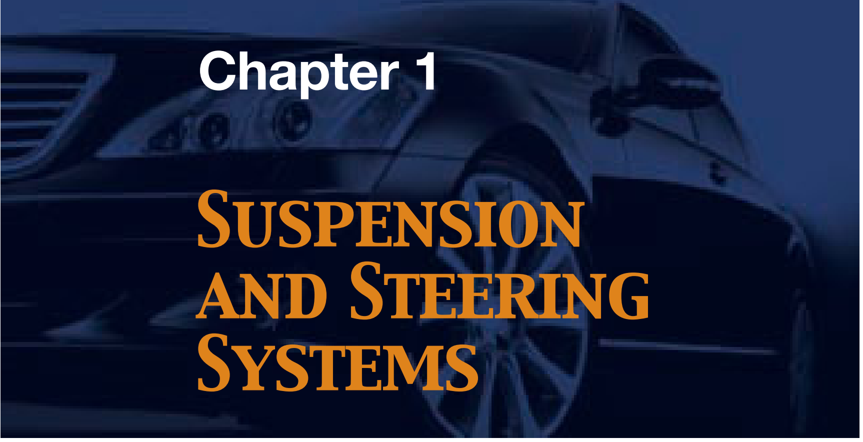

Chapter 1

Suspension and Steering Systems

Upon completion and review of this chapter, you should be able to understand and describe:

- How strength and rigidity are designed into a unitized body.
- The advantages of reduced vehicle weight.
- The design of a short-and-long arm (SLA) front suspension system.
- How limited independent rear wheel movement is provided in a semi-independent rear suspension system.
- The advantage of an independent rear suspension system.
- The purposes of vehicle tires.
- The terms positive and negative offset as they relate to vehicle wheel rims.
- Three different loads that are applied to wheel bearings.
- The purposes of shock absorbers.
- The difference between a shock absorber and a strut.
- Two different types of computer-controlled shock absorbers.
- The advantages of computer-controlled suspension systems.
- Two types of steering linkages.
- How the rack is moved in a rack and pinion steering gear.
- How a power steering pump develops hydraulic pressure.
- The advantages of four-wheel steering.
- The result of incorrect rear wheel toe.
- Front wheel caster.
- The results of excessive negative camber.

Introduction

The suspension system must provide proper steering control and ride quality. Performing these functions is extremely important to maintain vehicle safety and customer satisfaction. For example, if the suspension system allows excessive vertical wheel oscillations, the driver may lose control of the steering when driving on an irregular road surface. This loss of steering control can result in a vehicle collision and personal injury. Excessive vertical wheel oscillations transfer undesirable vibrations from the wheel(s) to the passenger compartment, which causes customer dissatisfaction with the ride quality.

The suspension system and frame must also position the wheels and tires properly to provide normal tire life and proper steering control. If the suspension system does not position each wheel and tire properly, wheel alignment angles are incorrect and usually cause excessive tire tread wear. Improper wheel and tire position can also cause the steering to pull to one side. When the suspension system positions the wheels and tires properly, the steering should remain in the straight-ahead position if the car is driven straight ahead on a

reasonably straight, smooth road surface. However, if the wheels and tires are not properly positioned, the steering can be erratic, and excessive steering effort is required to maintain the steering in the straight-ahead position.

The steering system is also extremely important to maintain vehicle safety and reduce driver fatigue. For example, if a steering system component is suddenly disconnected, the driver may experience a complete loss of steering control, resulting in a vehicle collision and personal injury. Loose steering system components can cause erratic steering, which causes the driver to continually turn the steering wheel in either direction to try and keep the vehicle moving straight ahead. This condition results in premature driver fatigue.

Frames and Unitized Bodies

Some vehicles, such as rear-wheel-drive cars, sport utility vehicles (SUVs), and trucks, have a frame that is separate from the body (Figure 1-1). Other vehicles have a unitized body that combines the frame and body in one unit, eliminating the external frame (Figure 1-2). In a unitized body, the body design rather than a heavy steel frame provides strength and rigidity. All parts of a unitized body are load-carrying members, and these body parts are welded together to form a strong assembly.

The frame or unitized body serves the following purposes:

1. Allows the vehicle to support its total weight, including the weight of the vehicle and cargo.
2. Allows the vehicle to absorb stress when driving on rough road surfaces.
3. Enables the vehicle to absorb torque from the engine and drive train.
4. Provides attachment points for suspension and other components.

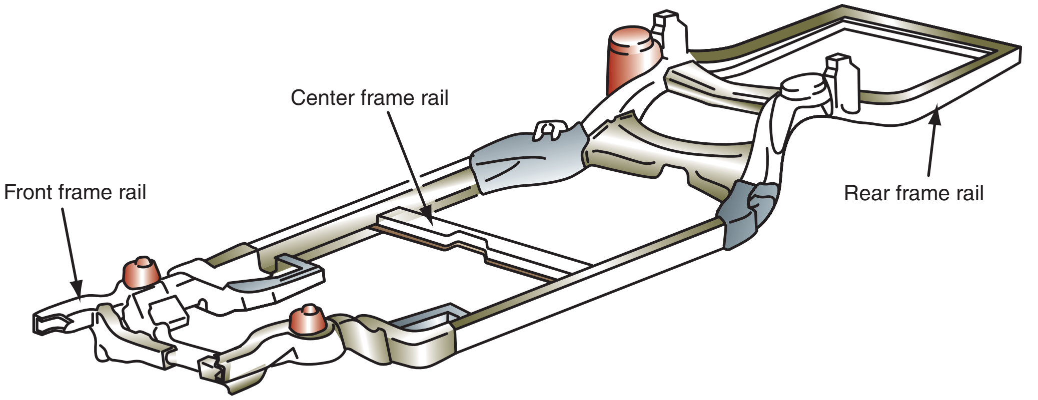

FIGURE 1-1 **Vehicle frame.**

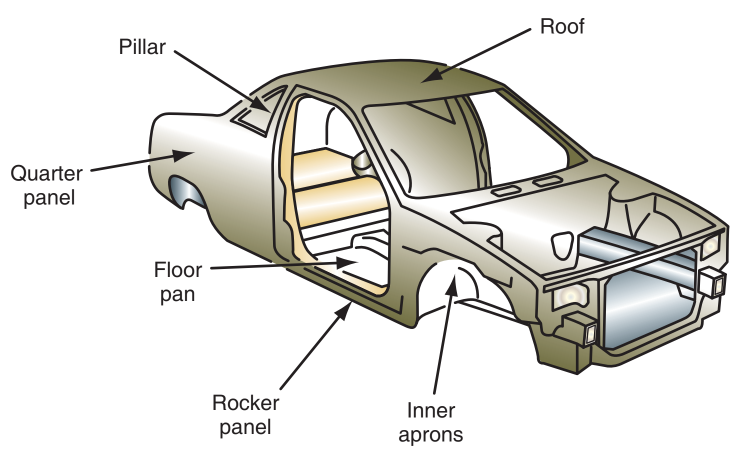

FIGURE 1-2 **Unitized body design.**

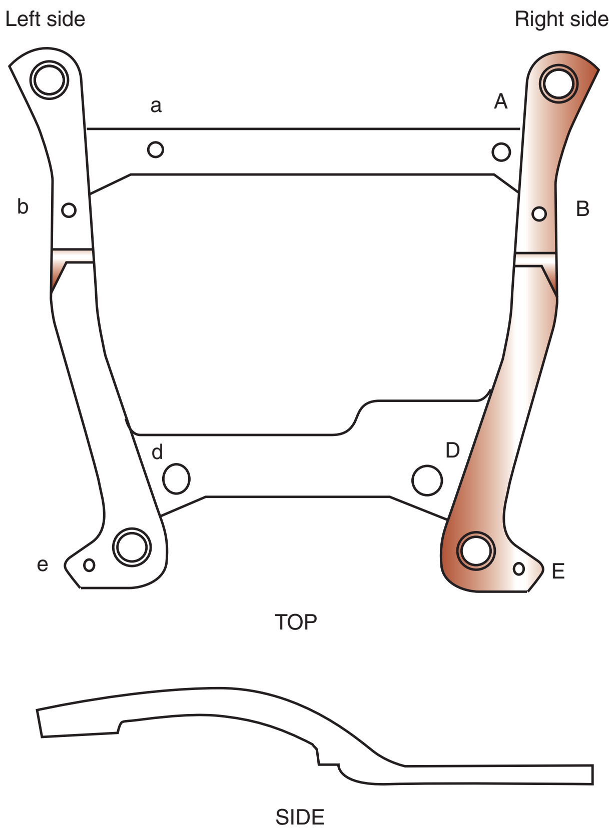

FIGURE 1-3 **Engine cradle.**

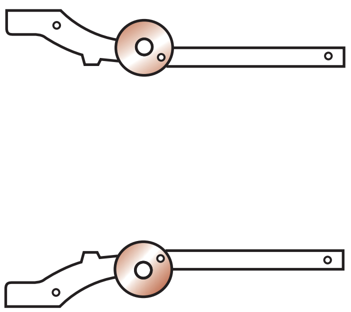

FIGURE 1-4 **Rear partial frame.**

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Carbon dioxide is a byproduct of the gasoline, diesel fuel, or ethanol combustion process.

A **greenhouse gas** is one that collects high in the earth's atmosphere and covers the earth like a blanket, due to which more heat is retained on the planet.

In the United States, it is estimated that automobiles contribute 1.5 billion tons of CO_2 to the atmosphere each year. Coal-burning power plants produce 2.5 billion tons of CO_2 each year.

The unitized body provides a steel box around the passenger compartment to provide passenger protection in a collision. In most unitized bodies, special steel panels are inserted in the doors to protect the vehicle occupants in a side collision. Some unitized body components are manufactured from high-strength or ultra high-strength steels. The unitized body design is typically used in small- and mid-sized front-wheel-drive cars. A steel cradle is mounted under the front of the unitized body to support the engine and transaxle (Figure 1-3). Rubber and steel mounts support the engine and transaxle on the cradle. Large rubber bushings are mounted between the cradle and the unitized body to help prevent engine vibration from reaching the passenger compartment. Some unitized bodies have a partial frame mounted under the rear of the vehicle to provide additional strength and facilitate the attachment of rear suspension components (Figure 1-4).

Vehicle weight plays a significant role in fuel consumption. One automotive design engineer states that "Fuel economy improvements are almost linear with weight reduction. A 30 percent reduction in vehicle weight provides approximately a 30 percent improvement in fuel economy." If a Toyota Prius weighs 3,300 lb (1,497 kg) and provides 50 miles per gallon (mpg), the same Prius would provide 55 mpg if it weighed 3,000 lb (1,360 kg).

Carbon dioxide (CO_2) emissions are a major concern for automotive manufacturers, because CO_2 is a **greenhouse gas** that contributes to global warming. Vehicle manufacturers are facing increasingly stringent CO_2 emission standards. CO_2 emissions are proportional to fuel consumption. Reduced fuel consumption results in lower CO_2 emissions. Therefore, reducing vehicle weight results in less fuel consumption and lower CO_2 emissions. Reduced weight also contributes to improved vehicle performance.

It is estimated that for every gallon of gasoline burned, 28 lb (12.7 kg) of CO_2 are released into the atmosphere. Approximately, 21 lb (9.53 kg) comes directly from the tailpipe of a vehicle, and 7 lb (3.18 kg) comes from the extraction, transportation, and refining of the gasoline.

When coil-type suspension springs are manufactured from titanium rather than steel, the weight saving per vehicle is 44 to 55 lb (20–25 kg).

The average car manufactured in the United States contains 347 lb (157 kg) of aluminum. A decade ago, the average car contained 242 lb (110 kg) of aluminum, and in 1973, the average car contained 81 lb (37 kg) of aluminum.

When vehicle bodies, front and rear suspension systems, and steering systems are built from lighter-weight components, these items can make an important contribution to improved fuel economy and reduced CO_2 emissions. The components in these systems may be manufactured from high-strength steels, aluminum, magnesium, titanium, or carbon composites to reduce vehicle weight. The Corvette Z06 has a hydro-formed aluminum frame to reduce vehicle weight. Light-weight aluminum construction throughout the Jaguar XK results in a vehicle weight of 3,671 lb (1,665 kg), which is 450 lb (204 kg) lighter than its Mercedes-Benz SL500 competitor that primarily uses steel construction. A new model Ford Fiesta is available in Europe since October 2008 and from later on in the United States and other countries. In this model, 55 percent of the unitized body structure is made from high-strength steels, making the body 10 percent stiffer torsionally than its predecessor and providing a very rigid safety cell surrounding the occupants. Ford says this model is 88 lb (44 kg) lighter than the previous model and more fuel and CO_2 efficient.

High material and production costs have prevented the use of carbon composites in production vehicles. Carbon composites have been used in some exotic ultra high-performance or race cars, where cost was not a factor. Carbon composites provide reduced weight and improved crash energy absorption. New carbon composites and improved manufacturing processes may soon make the use of some carbon composite components a reality in high-production vehicles.

Front Suspension Systems

The front and rear suspension systems are extremely important to provide proper wheel position, steering control, ride quality, and tire life. The impact of the tires striking road irregularities must be absorbed by the suspension systems. The suspension systems must supply proper ride quality to maintain customer satisfaction and reduce driver fatigue, as well as provide proper wheel and tire position to maintain directional stability when driving. Proper wheel position also ensures normal tire tread life.

Typical components in a short-and-long arm (SLA) front suspension system are illustrated in Figure 1-5. This type of front suspension system has a long lower control arm and a shorter upper control arm. The main front suspension components serve the following purposes:

1. Upper and lower control arms—control lateral (side-to-side) wheel movement.
2. Upper and lower control arm bushings—allow upward and downward control arm movement and absorb wheel impacts and vibrations.

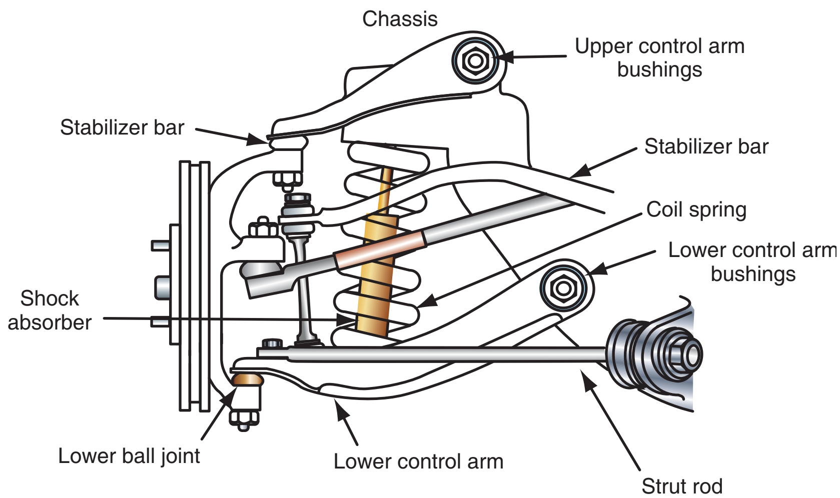

FIGURE 1-5 **Typical short-and-long arm (SLA) front suspension system.**

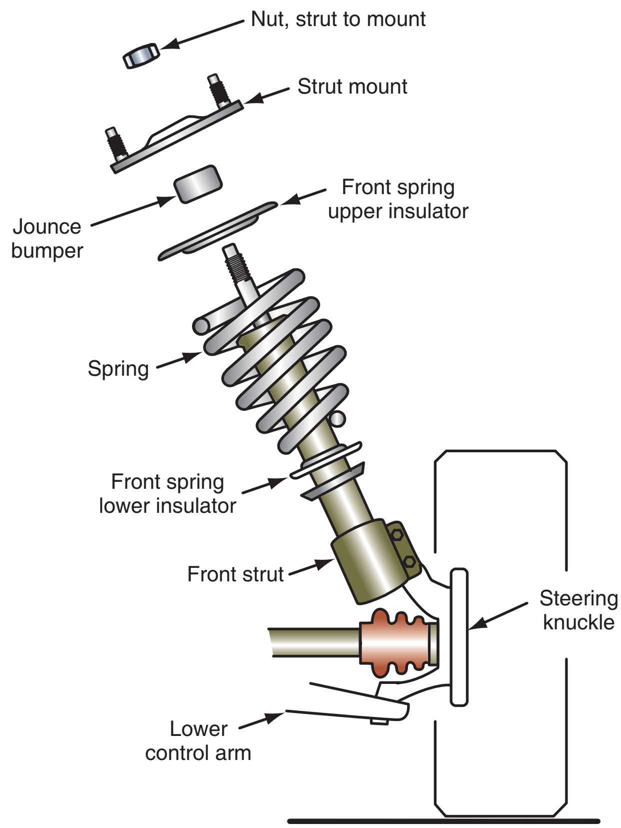

FIGURE 1-6 **Typical MacPherson strut front suspension system.**

3. Coil springs—allow proper suspension ride height and control suspension travel during driving maneuvers.
4. Ball joints—allow the knuckle and wheels to turn to the right or left.
5. Steering knuckles—provide mounting surfaces for the wheel bearings and hubs.
6. Shock absorbers—control spring action when driving on irregular road surfaces.
7. Strut rod—controls fore-and-aft wheel movement.
8. Stabilizer bar—reduces body sway when a front wheel strikes a road irregularity.

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A MacPherson strut front suspension system has no upper control arm and ball joint; instead, a strut is connected from the top of the knuckle to an upper strut mount bolted to the reinforced strut tower in the unitized body (Figure 1-6). The strut supports the top of the knuckle and also performs the same function as the shock absorber in a SLA suspension system. The coil spring is mounted between a lower support on the strut and the upper strut mount. Insulators are mounted between the ends of the coil spring and the mounting locations. A bearing in the upper strut mount allows the strut and coil spring to rotate with the spindle when the front wheels are turned.

Rear Suspension Systems

A typical live-axle rear suspension system has a one-piece rear axle housing. Trailing arms are connected from the rear axle housing to the chassis through rubber bushings. The coil springs are mounted between the trailing arms and the chassis (Figure 1-7). Because the rear axle housing is a one-piece assembly, vertical movement of one rear wheel causes the

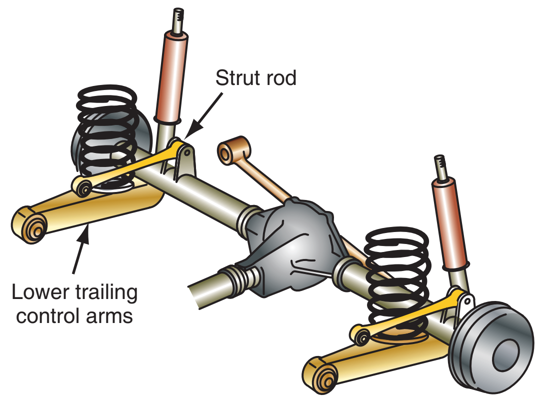

FIGURE 1-7 **Live-axle rear suspension system with coil springs.**

opposite rear wheel to be tipped outward at the top. This action increases tire tread wear and reduces ride quality and traction between the tire tread and road surface.

Many front-wheel drive cars have a semi-independent rear suspension system with an inverted steel U-section connected between the rear spindles (Figure 1-8). The inverted U-section usually contains a tubular stabilizer bar. When one rear wheel strikes a road irregularity, the inverted U-section and stabilizer bar twist, allowing some independent rear wheel movement before the wheel movement affects the opposite rear wheel. Some semi-independent rear suspension systems have a track bar and brace connected from the inverted U-section to the chassis to reduce lateral rear axle movement (Figure 1-9).

Many vehicles have an independent rear suspension system, wherein each rear wheel can move independently without affecting the position of the opposite rear wheel. This type of suspension system reduces rear tire wear and provides improved steering control. Independent rear suspension systems have a number of different configurations. A MacPherson strut independent rear suspension system has a strut and coil spring assembly connected from the top of the spindle through a upper strut mount to the chassis (Figure 1-10). No provision for strut rotation is required, because the rear wheels are not steered. Some independent rear suspension systems have a multilink design, wherein an adjustment link connected from the rear spindle to the chassis allows rear wheel position adjustment (Figure 1-11).

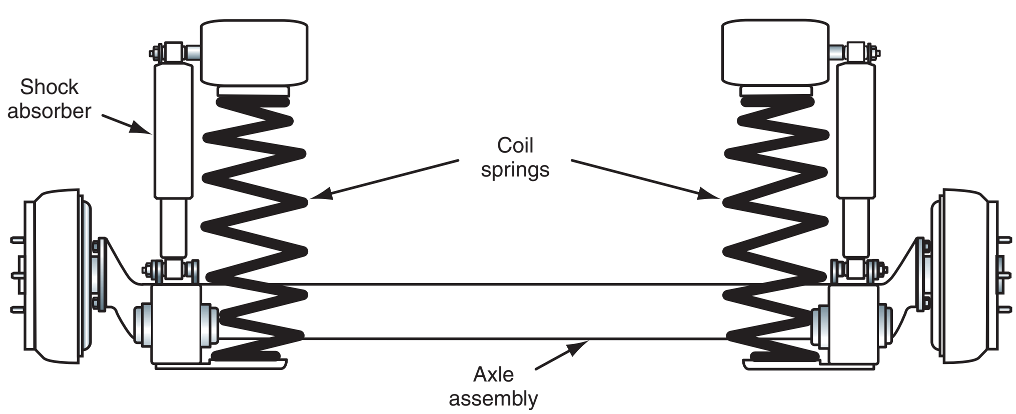

FIGURE 1-8 **Semi-independent rear suspension system.**

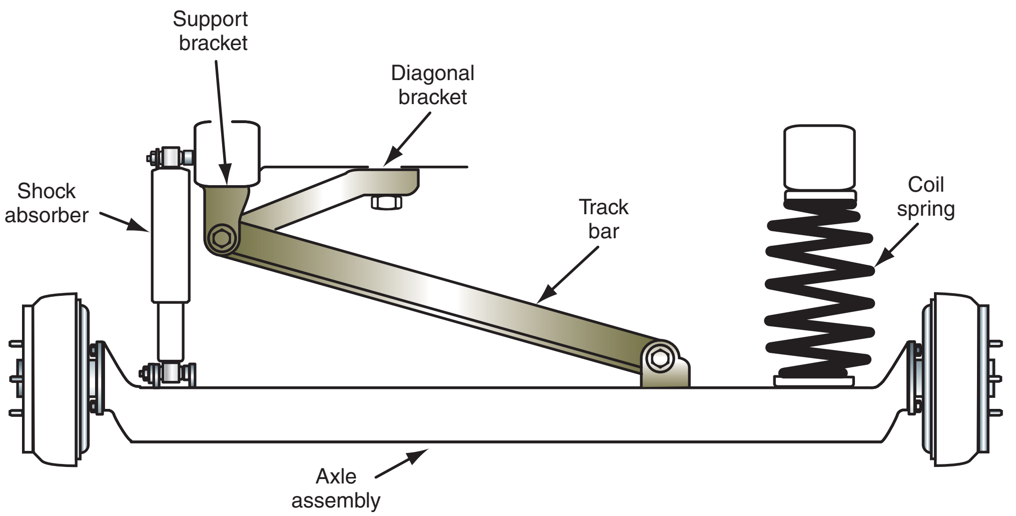

FIGURE 1-9 **Semi-independent rear suspension system with track bar and brace.**

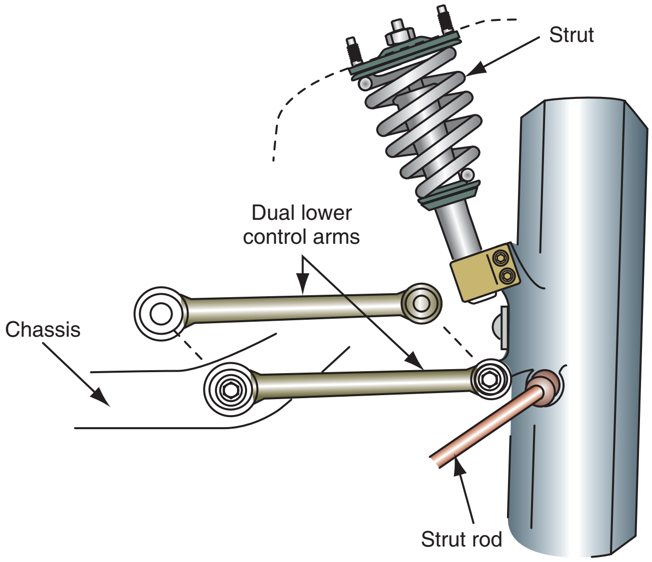

FIGURE 1-10 **MacPherson strut independent rear suspension system.**

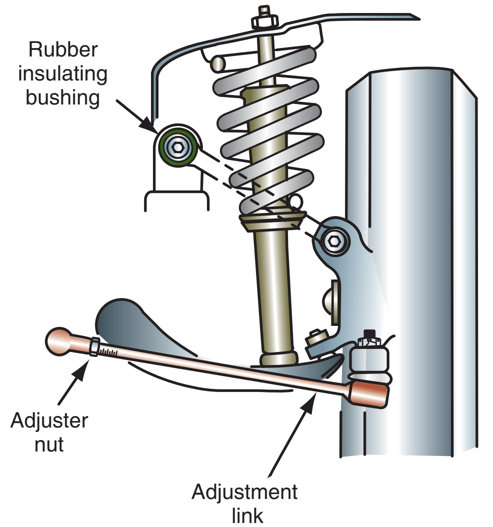

FIGURE 1-11 **Short-and-long arm independent rear suspension system.**

Tires, Wheels, and Hubs

Tire Purpose

Tires are extremely important because they play a large part in providing vehicle safety and ride quality! Tires are the only point of contact between the vehicle and the road surface. Vehicle tires provide these functions:

1. Tires must support the vehicle weight safely and firmly.
2. Tires must provide a comfortable ride.
3. Tires must supply adequate traction on various road surfaces to drive and steer the vehicle.
4. Tires must contribute to proper steering control and directional stability of the vehicle.
5. Tires must absorb high stresses when cornering, accelerating, and braking.
6. Tire treads must be designed to propel water off the tread and away from the tire when driving on wet highways. This action prevents water from lifting the tires off the road surface, which decreases tire traction.

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Wheel Rim Purpose

Wheel rims can be manufactured from steel, cast aluminum, forged aluminum, pressure-cast chrome-plated aluminum, or magnesium alloy. Wheel rims must retain the tires safely under all operating conditions without distortion. Tire and wheels must form air-tight containers at all temperatures so air does not leak from the assembly. Wheel rims must position the tires at the proper distance inward or outward from the vertical mounting surface of the wheel. The distance between the vertical wheel rim mounting surface and the centerline of the wheel rim is called **wheel offset** (Figure 1-12). If the wheel centerline is located inboard from the vertical wheel mounting surface, the wheel has **positive offset**. Conversely, if the wheel centerline is located outboard from the vertical wheel mounting surface, the wheel has **negative offset**. Wheel rims typically have four to six mounting openings that fit over studs in the wheel hub. When a wheel rim is installed on the hub studs, tapered nuts are then tightened to the specified torque to retain the wheel and tire assembly on the hub. On many wheel rims, the openings in the wheel rim are tapered to match the tapers on the retaining nuts. These tapered openings and matching tapered nuts center the wheel rim on the hub.

WARNING: Wheel nuts must be tightened in the proper sequence to the specified torque. Failure to follow the proper wheel nut tightening procedure and torque may cause a wheel to come off a car while driving. This action usually results in serious personal injury and extensive vehicle and/or property damage.

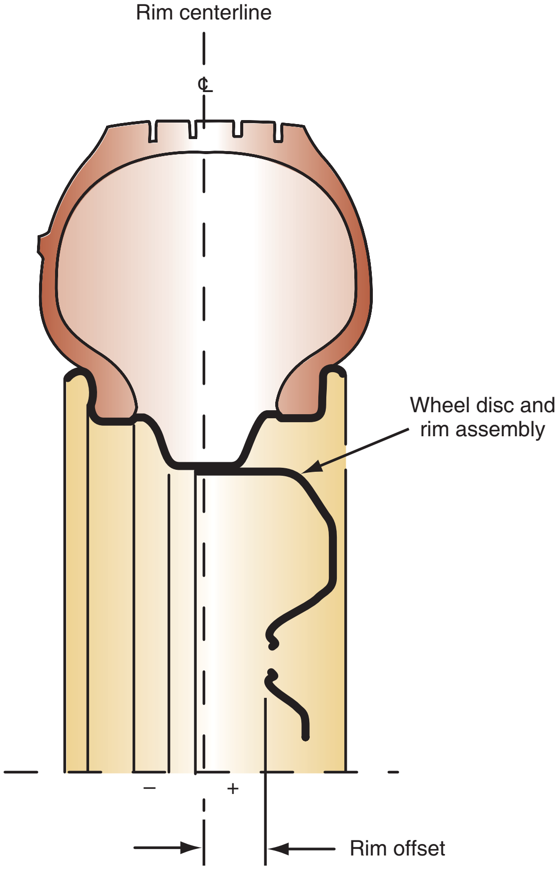

FIGURE 1-12 **Wheel rim design.**

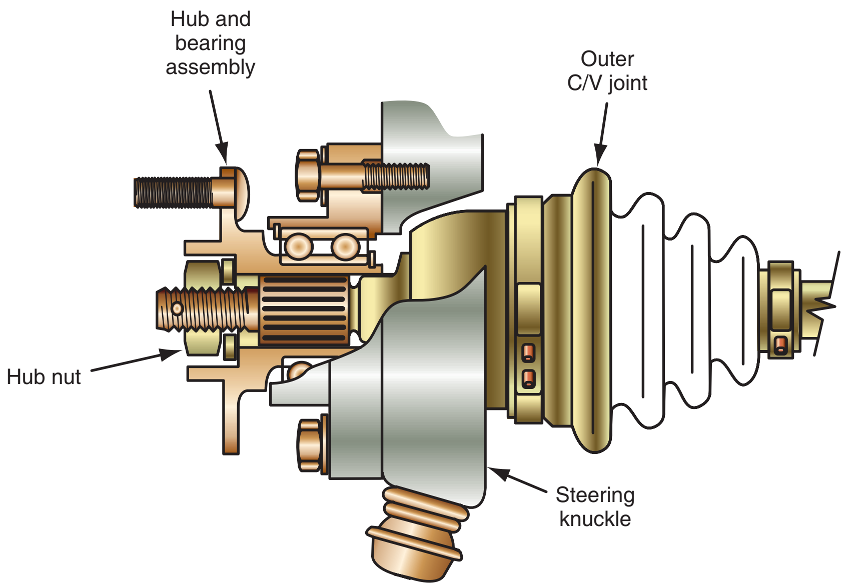

FIGURE 1-13 **Wheel bearing and hub assembly.**

Wheel Hubs

Wheel hubs must provide a secure mounting surface for the wheel rim and tire assembly. Wheel hubs also contain the wheel bearings that provide smooth wheel rotation with reduced friction. Wheel bearings must have a minimum amount of end play to greatly reduce wheel lateral movement. The wheel hub and bearing assemblies must carry the load supplied by the vehicle weight, and these assemblies must also guide the wheel and tire assembly (Figure 1-13). The vehicle weight is supplied to the wheel hub and bearing assembly in a vertical direction. This type of bearing load is called a **radial bearing load**. When the vehicle turns a corner, the wheel hubs and bearings must carry **thrust bearing loads** supplied in a horizontal direction and **angular bearing loads** supplied in a direction between the horizontal and the vertical.

Shock Absorbers and Struts

Each corner of the vehicle has a shock absorber or strut connected from the suspension system to the chassis. Shock absorbers control spring action and wheel oscillations to provide a comfortable ride. Controlling spring action and wheel oscillations also improve vehicle safety because the struts help to keep each tire tread in contact with the road surface. If the struts are worn out, excessive wheel oscillations when driving on irregular road surfaces can cause the driver to lose control of the vehicle. Struts also reduce body sway and lean while turning a corner. Struts reduce the tendency of the tire tread to lift off the road surface. This action improves tire tread life, traction, steering control, and directional stability.

Struts contain a sealed lower chamber filled with a special oil. Many shock absorbers have a nitrogen gas charge on top of the oil. This gas charge helps to prevent the shock absorber oil from foaming. A circular steel mount containing a rubber bushing is attached to the bottom end of the lower chamber, and this lower mounting is bolted to the suspension system. The upper strut housing is connected to a piston rod that extends into the lower chamber. A piston valve assembly is attached to the lower end of the piston rod (Figure 1-14). The upper strut mount is similar to the lower mounting, and the upper mount is bolted to the chassis.

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When a wheel strikes a road irregularity, the wheel and suspension move upward, and the spring in the suspension system is compressed. This action forces the lower shock absorber chamber to move upward, and the oil must flow from below the shock absorber piston and valve to the area above the valve. Upward wheel movement is called **jounce travel**. The strut

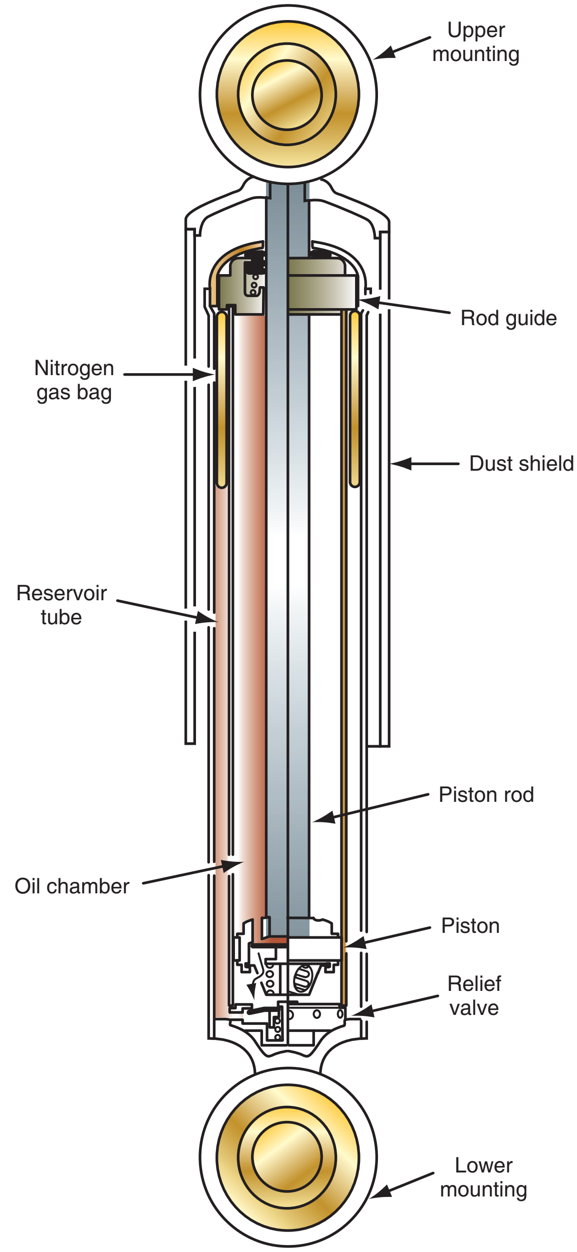

FIGURE 1-14 **Shock absorber design.**

valves are designed to provide precise oil flow control, and thus control the speed of upward wheel movement.

When a spring is compressed, it stores energy and then immediately expands with an equal amount of energy. When the spring expands, the tire and wheel assembly is forced downward. Under this condition, the lower strut chamber is forced downward, and oil must flow from above the shock absorber piston and valve to the area below the valve (Figure 1-15). Downward wheel movement is called **rebound travel**. The strut valves provide precise control of the oil flow, and this action controls spring action and wheel oscillations. Shock absorbers and valves are usually designed to provide more control during the rebound travel compared to the jounce travel.

Internal strut design is similar to shock absorber design, but struts also support the top of the steering knuckle. In most suspension systems, the lower end of the strut is attached to the top of the steering knuckle, and a special mount is connected between the upper end of the strut and the chassis (Figure 1-16). On front suspension systems, the upper strut mount

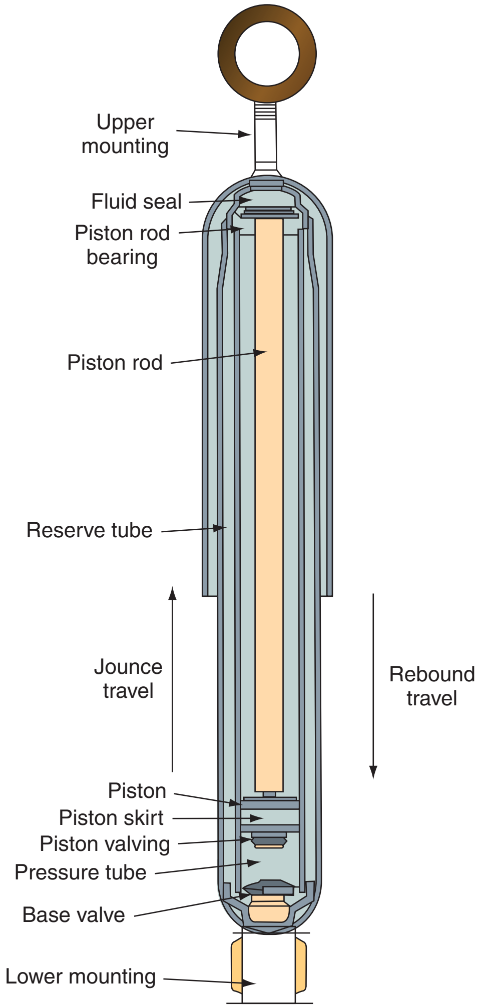

FIGURE 1-15 **Shock absorber action.**

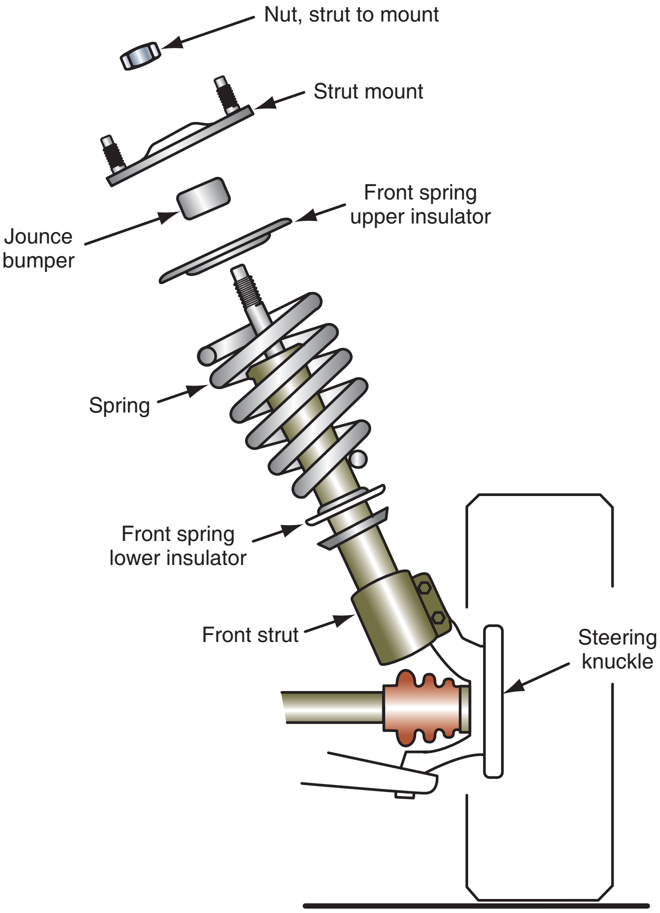

FIGURE 1-16 **Front strut and spring assembly.**

must allow strut and spring rotation when the front wheels are turned to the right or the left. The upper strut mount isolates wheel and suspension vibrations from the chassis.

Computer-Controlled Suspension Systems and Shock Absorbers

Many vehicles are equipped with computer-controlled suspension systems that provide a soft, comfortable ride for normal highway driving, and then automatically and very quickly switch to a firm ride for hard cornering, braking, or fast acceleration. Computer-controlled suspension systems reduce body sway during hard cornering, and thus contribute to improved ride quality and vehicle safety. Some computer-controlled suspension systems are driver-adjustable with up to four suspension modes to allow the driver to tailor the ride quality to the driving style.

Some computer-controlled suspensions systems have electronically actuated solenoids in each shock absorber or strut. These solenoids rotate the shock absorber or strut valves to adjust the valve openings and shock absorber control (Figure 1-17). Other shock absorbers or struts contain a magneto-rheological fluid which is a synthetic oil containing suspended iron particles. A computer-controlled electric winding is designed into the shock absorber housing. When there is no current flow through the winding, the iron particles are randomly dispersed in the oil. Under this condition, the oil consistency is thinner and the oil flows easily through the shock absorber valves to provide a softer ride. If the suspension computer

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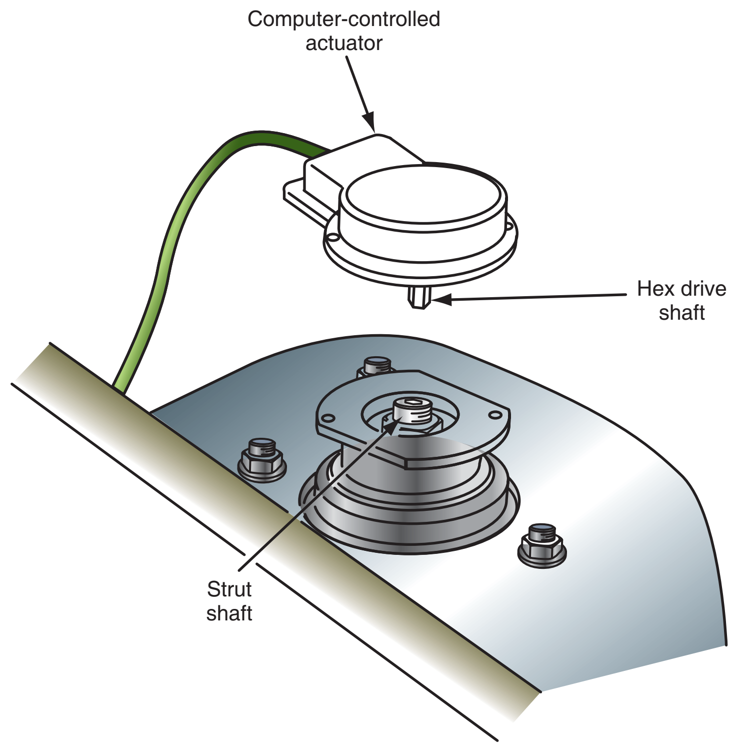

FIGURE 1-17 **Strut actuator.**

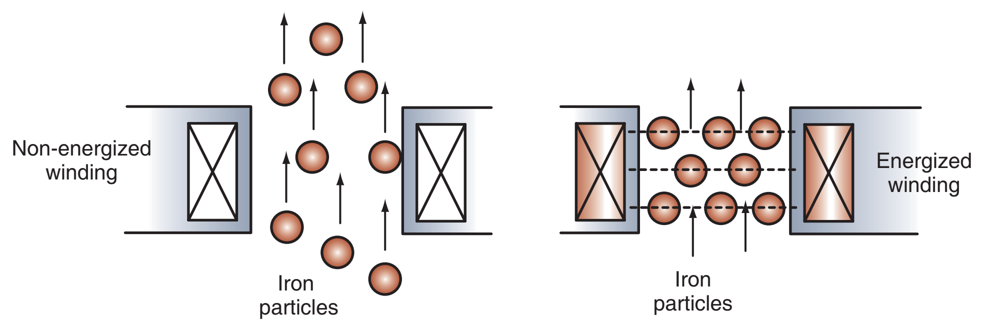

FIGURE 1-18 **Magneto-rheological fluid action in a strut or shock absorber.**

supplies current flow to the shock absorber windings, the iron particles are aligned so the oil has a jelly-like consistency (Figure 1-18). This action instantly provides a much firmer ride. The computer can provide a large variation in current flow through the shock absorber windings and a wide range of ride control. Input sensors at each corner of the vehicle inform the suspension computer the velocity of the wheel jounce and rebound, and the computer uses these input signals to operate the shock absorber windings or actuators.

AUTHOR'S NOTE: One of the advantages of computer-controlled shock absorbers and suspension systems is the speed at which modern computers can perform output functions. For example, a suspension computer can change the thickness of the magneto-rheological fluid in a shock absorber in about 1 millisecond (ms). When a wheel and tire strike a road irregularity and move upward, this fast computer action adjusts the thickness of the shock absorber fluid in relation to the wheel jounce velocity before the wheel moves downward in the rebound stroke and strikes the road surface.

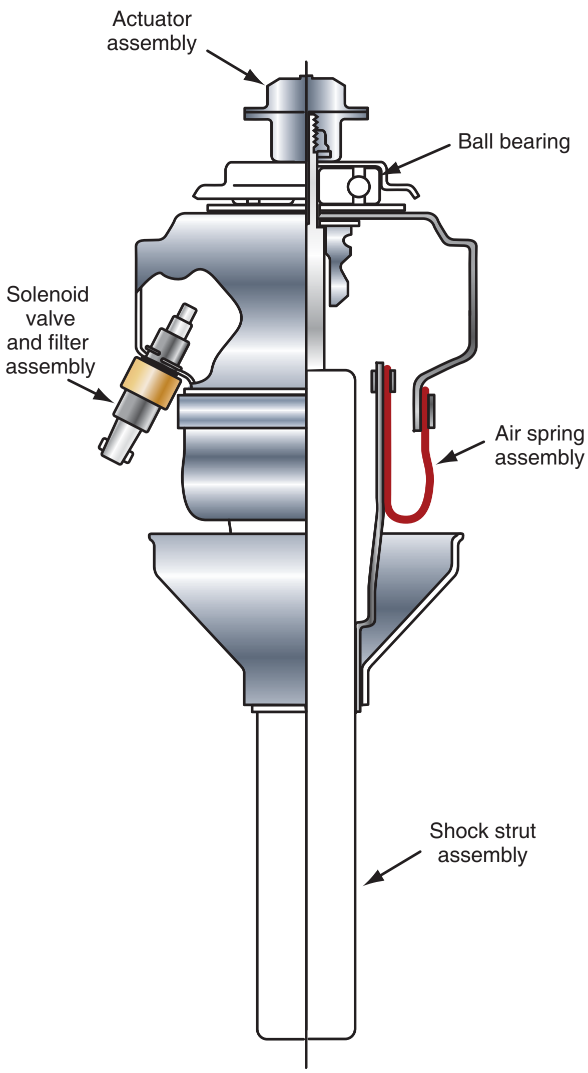

FIGURE 1-19 **Air spring and strut assembly.**

Some computer-controlled suspension systems have air springs in place of coil springs (Figure 1-19). Front and rear height sensors inform the suspension computer regarding the suspension height, and the computer operates an air compressor and air spring control valves to control the amount of air in the air springs, and thus control suspension height. Some air suspension systems also have computer-controlled shock absorbers or struts.

Steering Systems

Steering systems are essential to provide vehicle safety, steering quality, and steering control! Steering system problems can cause the steering to pull to one side when driving straight ahead, excessive steering effort, **wheel shimmy**, or excessive steering wheel free-play. These problems all reduce vehicle safety and increase driver fatigue. Therefore, steering systems must be properly maintained.

Wheel shimmy may be defined as rapid inward and outward wheel and tire oscillations.

Steering Columns and Steering Linkage Mechanisms

The steering column connects the steering wheel to the steering gear. The steering wheel is connected to the steering shaft, and this shaft extends through the center of the steering column. The lower end of the steering shaft is connected through a universal joint or flexible coupling to the shaft from the steering gear. The steering shaft is supported on bearings in

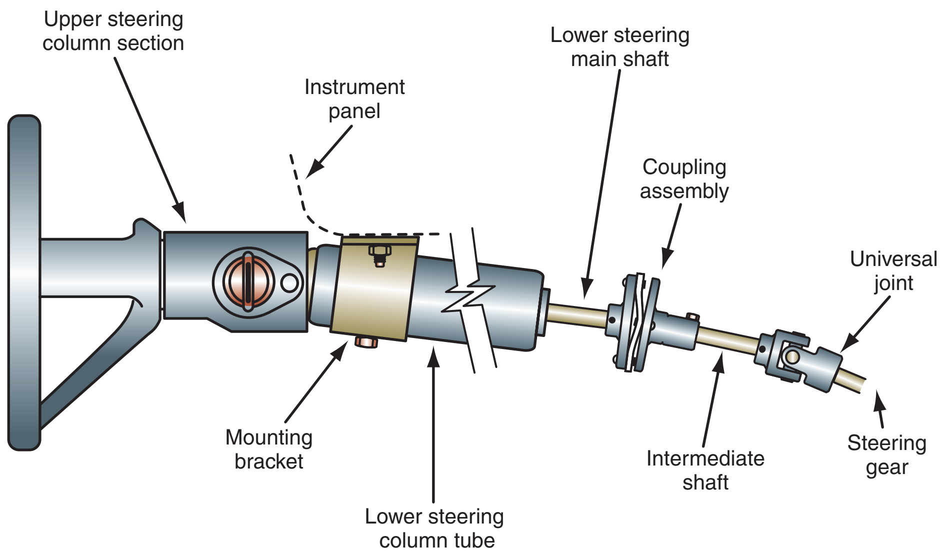

FIGURE 1-20 **Tilt steering column.**

the steering column. Some steering columns are designed to collapse or move away from the driver, if the driver is thrown against the steering wheel in a collision. Some steering columns are designed so the driver can tilt the steering wheel downward or upward to provide increased driver comfort and facilitate entering and exiting the driver's seat (Figure 1-20). Some steering columns also provide a telescoping action so the steering wheel can be moved closer to, or farther away from, the driver. Other steering columns do not have any tilt or telescoping action. A mounting bracket retains the steering column to the instrument panel.

On most vehicles, the ignition lock cylinder and ignition switch are mounted in the steering column. Removing the key from the ignition switch locks the steering column and the gear shift on many vehicles. The steering column usually contains a combination signal light, wipe/wash, dimmer, and cruise control switch. This switch may be called a smart switch. The switch for the hazard warning lights is also mounted in the steering column. An air bag inflator module is mounted in the top of the steering wheel, and a clockspring electrical connector under the steering wheel maintains electrical contact between the inflator module and the air bag electrical system.

Steering linkages connect the steering gear to the steering arms on the front wheels. In a parallelogram steering linkage, a pitman arm is connected from the steering gear to a center link (Figure 1-21). A pivoted idler arm bolted to the chassis supports the other end of the center link. Tie rods are connected from the center link to the steering arms attached to the front wheels. Pivoted ball studs are mounted in the inner ends of the tie rods, and outer tie rod ends are threaded into the tie rod adjusting sleeves. The outer tie rod ends contain pivoted ball studs, and these tapered studs fit into matching tapered openings in the outer ends of the steering arms. The pitman arm and idler arm position the center link so the tie rods are parallel to the lower control arms. This tie rod position is very important to maintain proper steering operation.

Many vehicles have a rack and pinion steering linkage. In these linkages, the tie rods are connected through inner tie rod ends to the rack in the rack and pinion steering gear. Outer tie rod ends are connected from the tie rods to the steering arms (Figure 1-22). In this type of steering linkage, the steering gear mounting must position the tie rods so they are parallel to the lower control arms. The rack and pinion steering gear can be mounted on the cowl or the front cross member.

CAUTION:

Regular inspection and maintenance of steering linkage components is very important to provide normal component life and maintain vehicle safety.

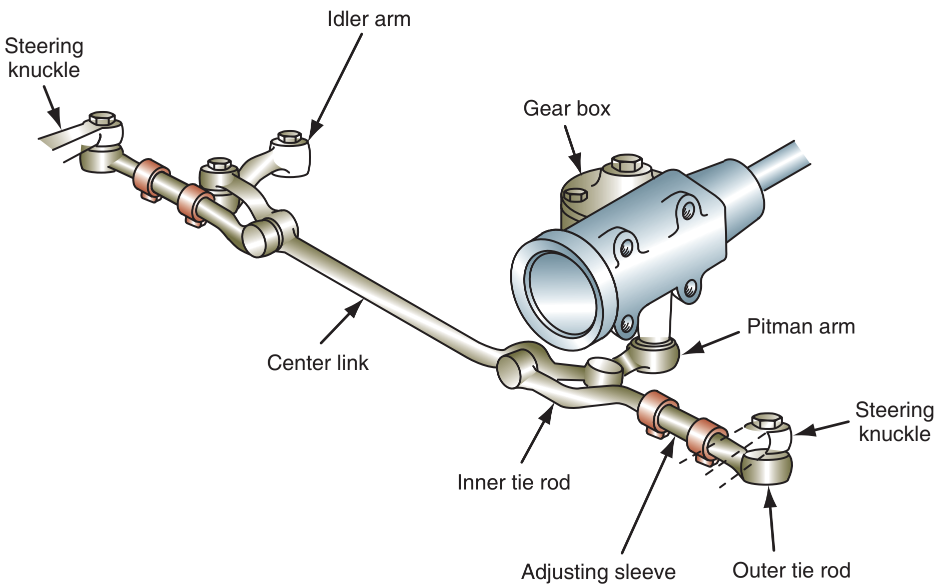

FIGURE 1-21 **Parallelogram steering linkage.**

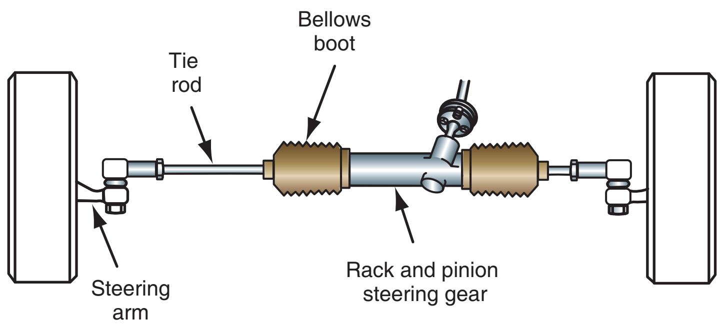

FIGURE 1-22 **Rack and pinion steering gear and linkage.**

Recirculating Ball Steering Gears

Some vehicles are equipped with a recirculating ball steering gear, wherein the steering shaft is attached to a worm gear in the steering gear. A ball nut with internal grooves is mounted over the worm gear. Ball bearings are mounted between the worm gear and ball nut grooves to reduce friction and provide reduced steering effort. Outer grooves on the ball nut are meshed with matching teeth on the sector shaft (Figure 1-23). The lower end of the sector shaft is splined to the pitman arm. When the steering wheel is turned, the ball nut moves upward or downward on the worm gear, which rotates the sector shaft to provide the desired steering action. Recirculating ball steering gears can be manual-type with no hydraulic assist, or power-type with hydraulic assist from the power steering pump.

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Rack and Pinion Steering Gears

Rack and pinion steering gears and linkages are more compact than recirculating ball steering gears and parallelogram steering linkages. Therefore, rack and pinion steering gears are usually installed on smaller, front-wheel drive vehicles. Rack and pinion steering gears transfer more road shock from the front wheels to the steering gear and steering wheel, because the tie rods are connected directly to the rack in the steering gear.

In a rack and pinion steering gear, a toothed rack is mounted on bushings in the rack housing. The rack teeth are meshed with teeth on a pinion gear mounted near one end of the gear. The pinion gear is mounted on bearings in the gear housing. The steering shaft from the steering column is attached to the upper end of the pinion gear (Figure 1-24). When the

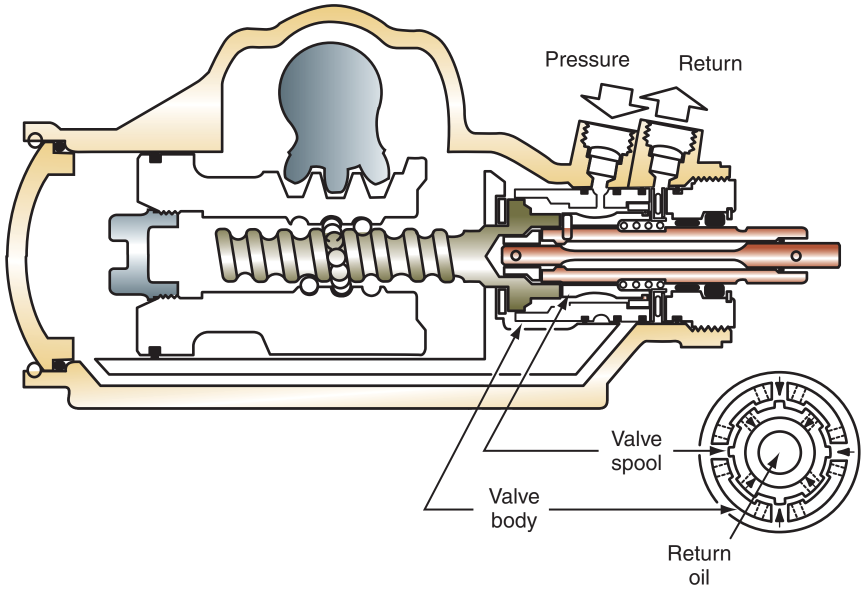


FIGURE 1-23 **Power recirculating ball steering gear.**

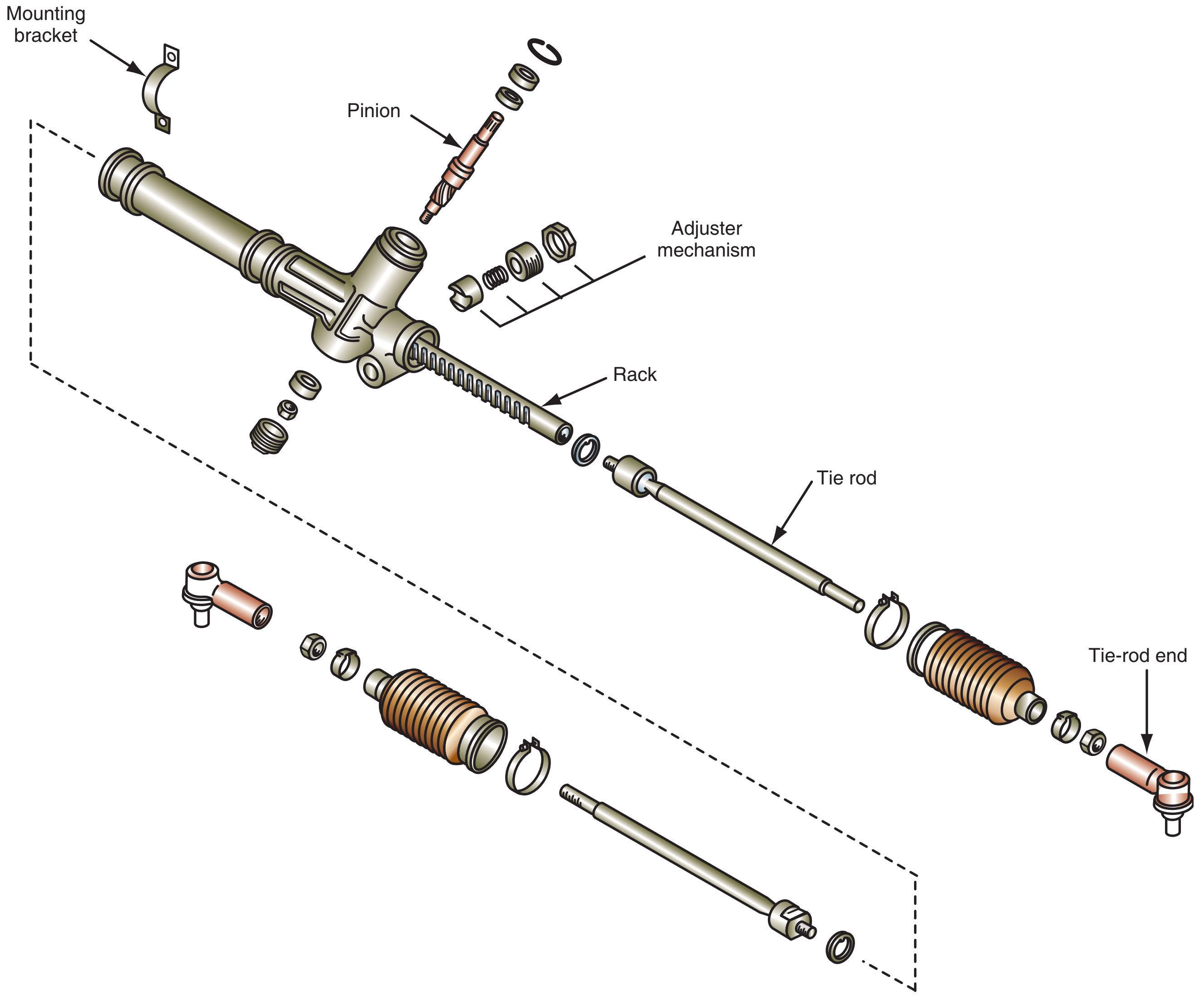


FIGURE 1-24 **Manual rack and pinion steering gear.**

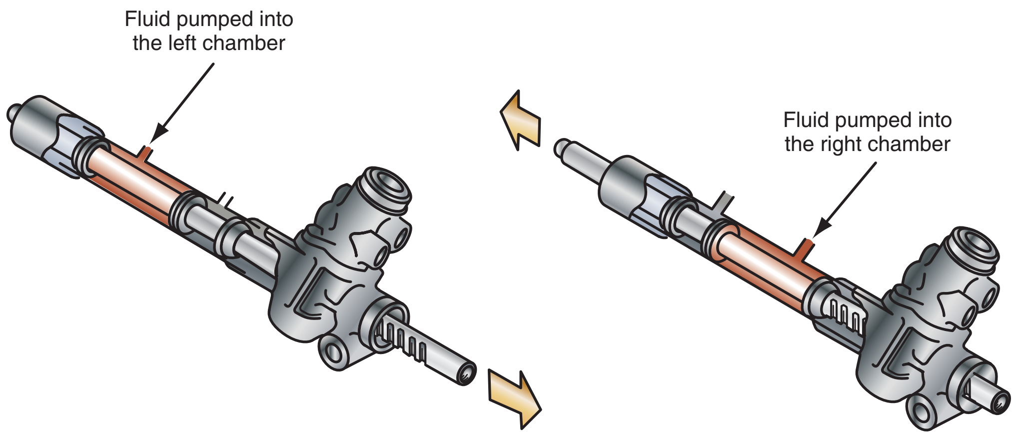


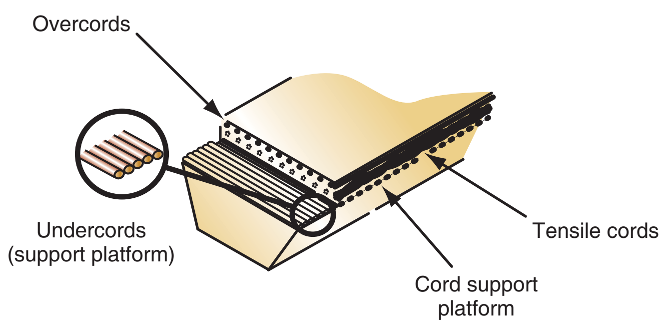
FIGURE 1-25 **Power rack and pinion steering gear with sealed rack piston chambers.**

steering wheel is turned, the rotation of the pinion gear moves the rack inward or outward to provide the desired steering action. Rack and pinion steering gears can be manual-type or power assisted by fluid pressure from the power steering pump. Power rack and pinion steering gears have a piston near the center of the rack, and fluid pressure is supplied from the power steering pump to sealed chambers on either side of the rack piston to provide steering assistance (Figure 1-25).

Power Steering Pumps

A belt surrounding the crankshaft pulley and the power steering pump pulley drives the power steering pump. The power steering pump drive belt can be a V-type (Figure 1-26) or a ribbed V-type (Figure 1-27). The ribbed V-belt contains a number of small, ribbed

A ribbed V-belt may be called a **serpentine belt.**



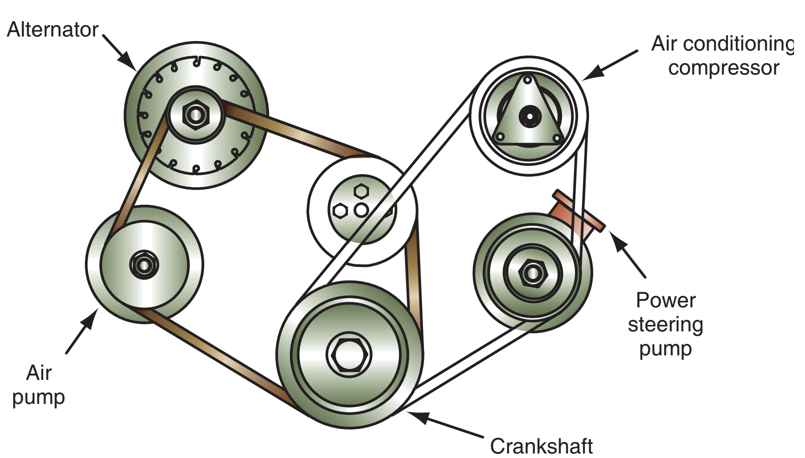


FIGURE 1-26 **Conventional V-belt.**

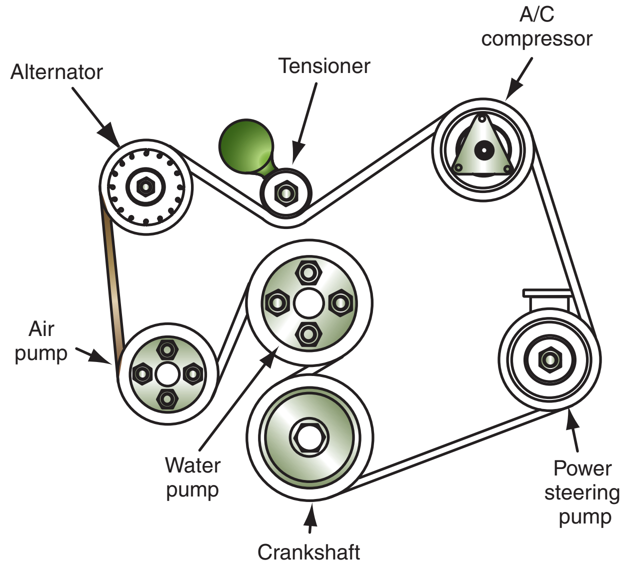


FIGURE 1-27 **Ribbed V-belt.**

grooves on the underside and a flat upper side. The ribbed V-belt surrounds the pulleys on all the belt-driven components, allowing these components to be on the same vertical plane. This arrangement saves a considerable amount of underhood space. The smooth side of the ribbed V-belt can be used to drive some components. Some vehicles have a V-belt driving a few components and a ribbed V-belt driving other compenents. Some power steering pumps have an integral fluid reservoir; other power steering systems have a remote fluid reservoir. The pump supplies fluid through a high-pressure hose to the steering gear, and the fluid is returned from the steering gear through a low-pressure hose to the pump (Figure 1-28). In some power steering pumps, the pump shaft is connected from the pulley to the rotor, and a number of vanes are mounted in rotor slots. The rotor and vane assembly rotates in the center of an elliptical cam ring. As the vanes rotate inside the cam ring, the spaces between the vanes change in volume. When the spaces between the vanes become smaller, pressure is applied to the fluid because the fluid cannot be compressed (Figure 1-29). This pressurized fluid is forced through the pump outlet fitting and high-pressure hose to the steering gear. A flow control valve with an integral pressure relief valve controls pump pressure.

Electronic Power Steering Gears

Some vehicles have an electronic power steering gear in place of the hydraulic power steering gear and pump. An electronic power steering gear contains a computer-driven reversible electric motor. The electronic power steering gear is similar to a rack and pinion steering gear, but contains an electric motor in place of hydraulic controls. The armature in the electric motor is connected through a set of gears to a worm shaft, and a ball nut is mounted over the worm shaft. The armature is hollow, and the rack extends through the armature. The ball nut and worm shaft are similar to the ones in a recirculating ball steering gear. The ball nut is coupled to the rack, and fields in the motor surround the armature (Figure 1-30).

When the computer supplies current to the armature, the armature rotates and turns the worm shaft. Worm shaft rotation moves the ball nut and helps to move the rack to the right or left to provide steering assistance. The power steering computer supplies current to the armature in the electric motor to help rotate the armature in the proper direction. Voltage signals are sent from a vehicle speed sensor (VSS) and steering wheel rotational sensor mounted on

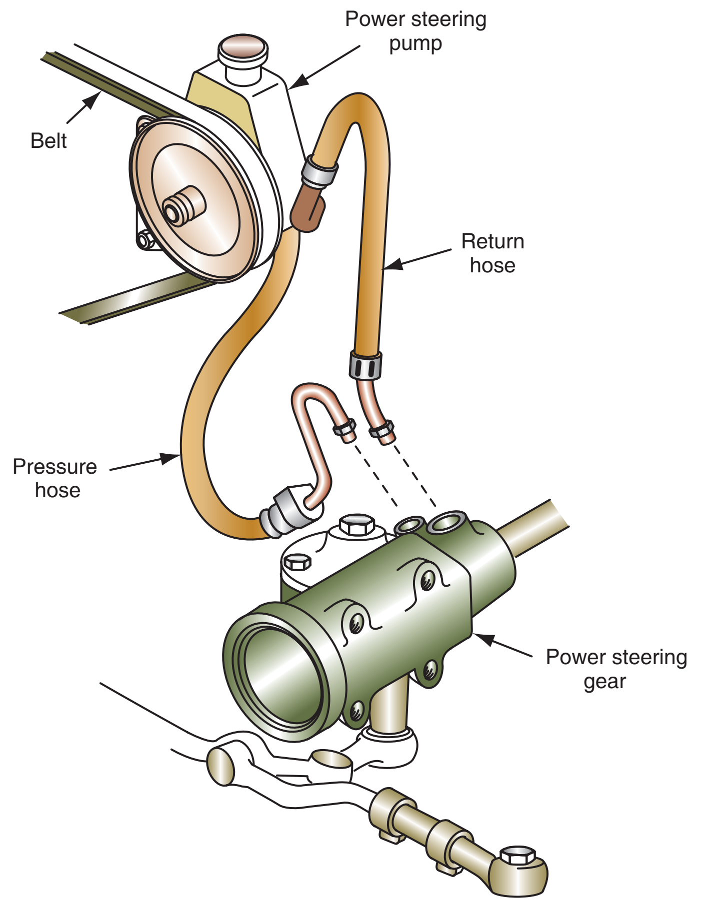


FIGURE 1-28 **Power steering system.**

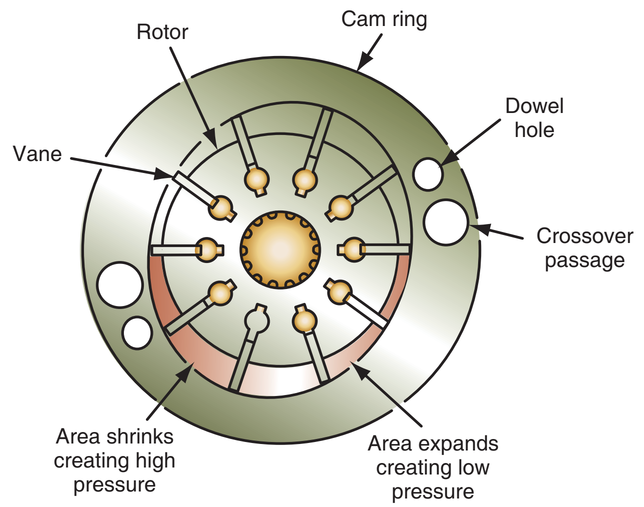


FIGURE 1-29 **Power steering pump rotor and vanes.**

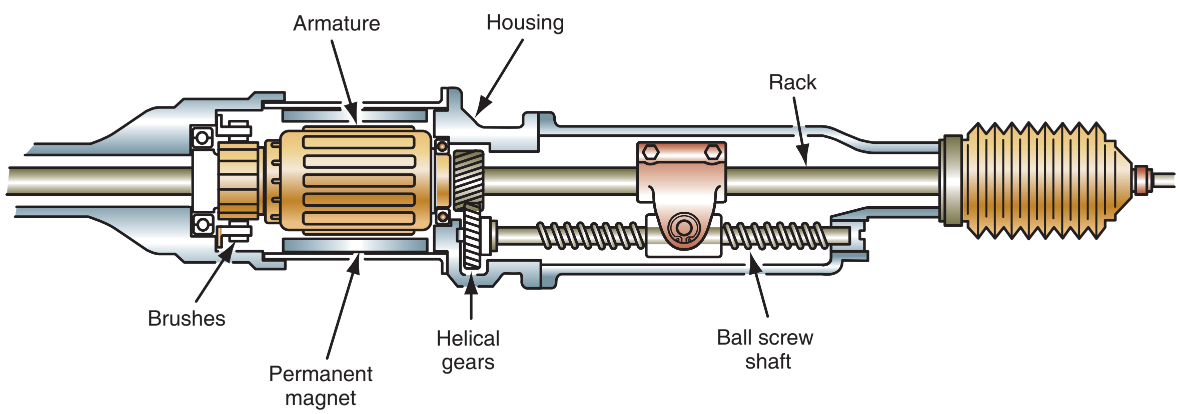


FIGURE 1-30 **Electronic power steering gear.**

the steering gear pinion. The computer uses this information to provide the proper amount and direction of current to the steering gear armature.

Four-Wheel Steering

Some vehicles are equipped with four-wheel steering, wherein a separate computer controls a rear, electronic power steering gear. The electric motor on the rear steering gear drives the steering gear pinion (Figure 1-31). Input signals are sent to the rear steering computer from

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Turning circle is the circle that a vehicle completes when it is driven with the steering wheel turned fully in one direction.

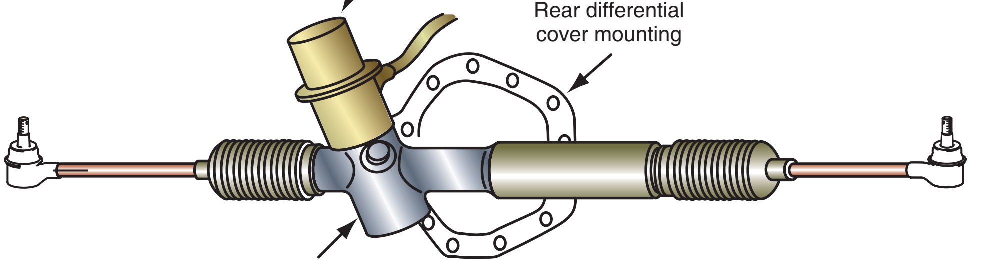

FIGURE 1-31 **Rear electronic power steering gear, four-wheel steering.**

Slideslip is the tendency of the rear wheels to slip sideways because of centrifugal force when a vehicle is cornering at higher speeds.

the front steering position sensor and the VSS. At low speeds, the computer and rear steering gear steer the rear wheels up to 12° in the opposite direction to the front wheels. The term **negative-phase steering** is applied to the mode when the rear wheels are steered in the opposite direction to the front wheels. This rear wheel steering action allows the vehicle to have a shorter **turning circle** and facilitates parking in small spaces. At higher vehicle speeds, the rear wheels are steered 1° in the same direction as the front wheels. The term **positive-phase steering** is applied to the mode when the rear wheels are steered in the same direction as the front wheels. This action reduces vehicle **sideslip** when changing lanes at higher speeds.

Wheel alignment is the proper positioning of the tire and wheel assemblies on the vehicle to provide normal tire tread life, precise steering control, and satisfactory ride quality.

Wheel Alignment

Proper **wheel alignment** is extremely important to provide steering control, ride quality, and normal tire tread life. Improper wheel alignment may cause steering wander, steering pull to the right or left, or improper steering wheel return after turning a corner. Incorrect wheel alignment may contribute to harsh ride quality. Wheel alignment angles that are not within specifications may cause rapid tire tread wear.

Rear Wheel Tracking

The **thrust line** is an imaginary line positioned at a 90° angle to the center of the rear axle and extending forward.

The rear wheels must track directly behind the front wheels to provide proper steering control. The front and rear wheels must be parallel to the vehicle centerline to provide proper rear wheel tracking. If the rear wheels are tracking directly behind the front wheels, the **thrust line** is positioned at the geometric centerline of the vehicle (Figure 1-32). If the left rear wheel has excessive **toe-out**, the thrust line is moved to the left of the geometric centerline (Figure 1-33). This improperly positioned thrust line causes the steering to pull to the right and also results in rapid tread wear on the left rear tire.

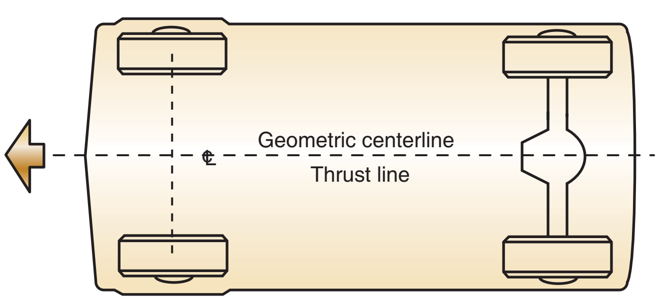

FIGURE 1-32 **Front and rear wheels are parallel to the vehicle centerline.**

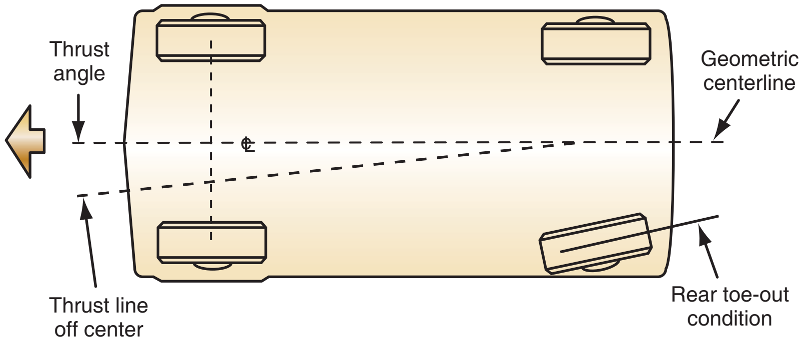

FIGURE 1-33 **Excessive toe-out on the left rear wheel moves the thrust line to the left of the geometric centerline.**

Rear Wheel Toe

A toe-out condition occurs when the distance between the front edges of the rear tires is greater than the distance between the rear edges of the rear tires. Toe-in occurs if the distance between the rear edges of the rear tires is greater than the distance between the front edges of the rear tires (Figure 1-34). On front-wheel-drive vehicles, driving forces tend to push the rear spindles backward. Therefore, these vehicles are usually designed with a zero toe-in or a slight toe-in. Improper rear wheel toe causes rapid tire tread wear because the wheel and tire assembly is being pushed sideways to a certain extent as the vehicle is driven. Steering pull to one side may also be a result of improper rear wheel toe.

Toe-out is a condition that occurs if the distance between the front edges of the front or rear tires is greater than the distance between the rear edges of the front or rear tires.

Rear Wheel Camber

Camber is the angle between the centerline of the wheel and tire in relation to the true vertical centerline of the wheel and tire viewed from the front. **Positive camber** occurs when the vertical centerline of the wheel and tire is tilted outward in relation to the true vertical centerline of the wheel and tire. **Negative camber** occurs if the vertical centerline of the wheel and tire is tilted inward in relation to the true vertical centerline of the wheel and tire (Figure 1-35). Excessive positive camber causes rapid wear on the outside edge of the

Positive camber is present when the vertical centerline of the tire is tilted outward in relation to the true vertical centerline of the tire.

Negative camber occurs if the vertical centerline of the tire is tilted inward in relation to the true vertical centerline of the tire.

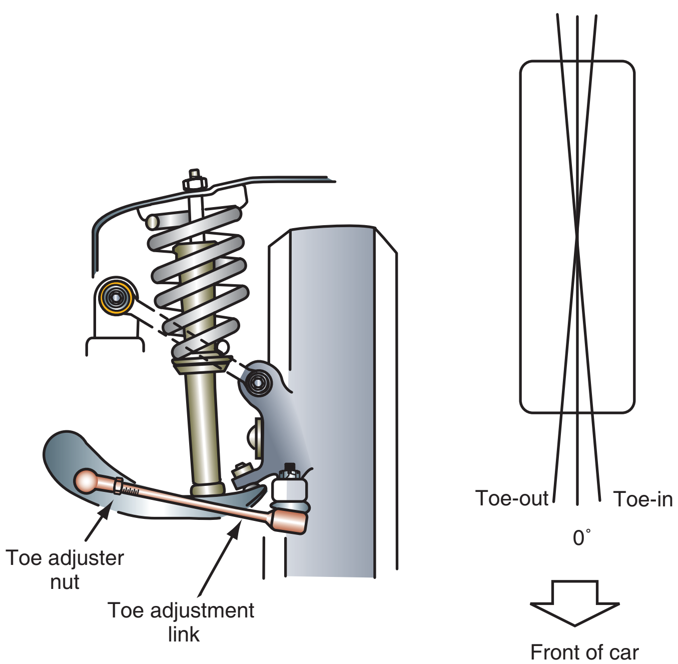

FIGURE 1-34 **Rear wheel toe.**

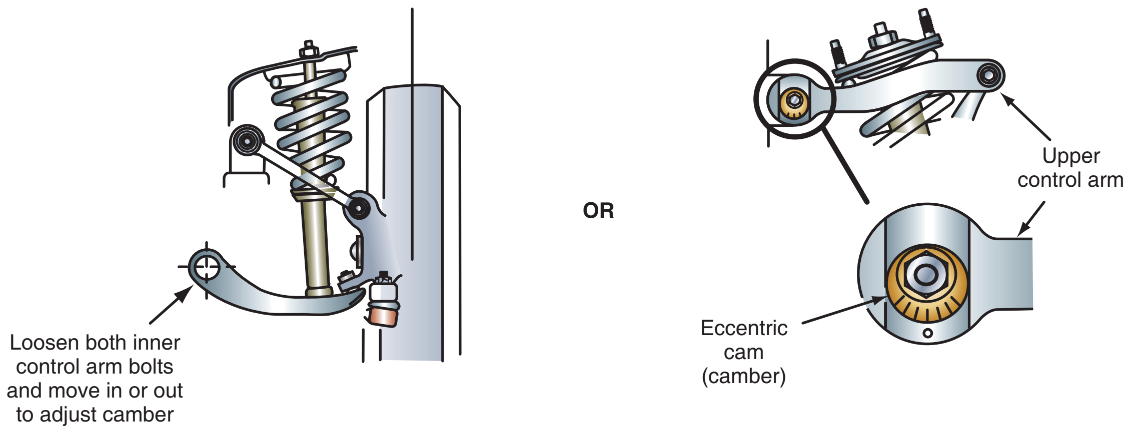

FIGURE 1-35 **Rear wheel camber.**

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tire tread, whereas excessive negative camber results in rapid wear on the inside edge of the tire tread. Because a tilted wheel and tire assembly always rolls in the direction of the tilt, improper camber angle on the front wheels may cause steering pull. Many front-wheel-drive vehicles have a slightly negative rear wheel camber that improves cornering stability.

Front Wheel Camber

Front wheel camber is the same as rear wheel camber except for the camber setting. Many front suspension systems are designed with a slightly positive camber.

Front Wheel Caster

Positive caster is the angle of a line through the center of the tire that is tilted rearward in relation to the true vertical centerline of the tire viewed from the side.

Negative caster is the angle of a line through the center of the tire that is tilted forward in relation to the true vertical centerline of the tire viewed from the side.

Caster is the tilt of a line through the tire centerline (steering axis) in relation to the true vertical tire centerline viewed from the side. **Positive caster** occurs when the centerline of the tire is tilted rearward in relation to the true vertical centerline of the tire. **Negative caster** occurs when the centerline of the tire is tilted forward in relation to the centerline of the tire viewed from the side (Figure 1-36). Excessive negative caster causes the steering to wander when the vehicle is driven straight ahead. Excessive positive caster causes increased steering effort and rapid steering wheel return after turning a corner. Harsh ride quality is also a result of excessive positive caster because this condition causes the caster line to be aimed at road irregularities.

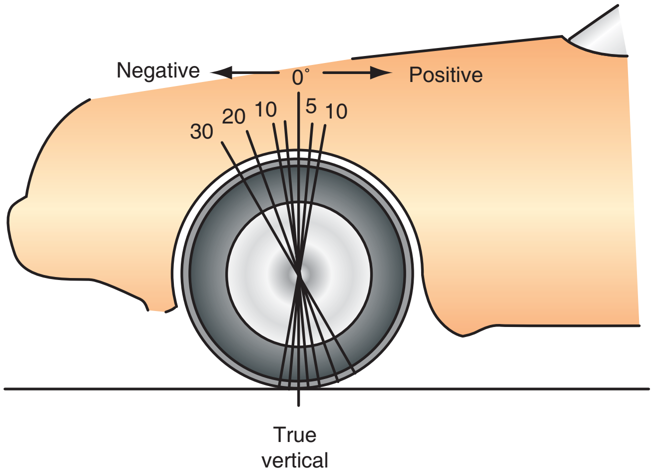

FIGURE 1-36 **Positive and negative caster.**

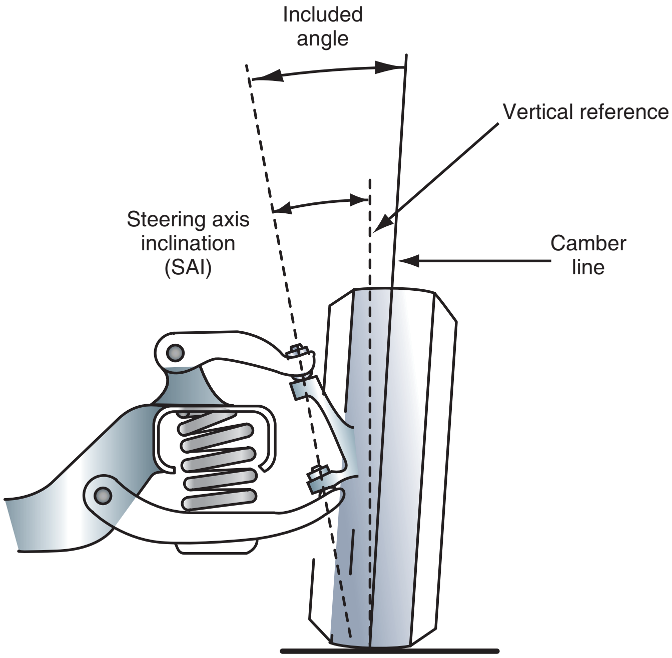

FIGURE 1-37 **Steering axis inclination and included angle.**

Steering axis inclination (SAI) is the angle of a line through the center of the upper strut mount and the lower ball joint in relation to the true vertical centerline of the tire viewed from the front of the vehicle.

Included angle is the sum of the SAI and the camber angle.

Steering Axis Inclination

Steering axis inclination (SAI) is the angle of a line through the centerline of the upper strut mount and the lower ball joint in relation to the true vertical centerline of the tire viewed from the front of the vehicle (Figure 1-37). The **included angle** is the sum of the SAI and camber angle. If the camber angle is negative, this angle must be subtracted from the SAI to calculate the included angle. When the SAI angle is tilted toward the center of the vehicle and the wheels are straight ahead, the height of the front spindles are raised closer to the chassis. This action allows gravity to lower the height of the vehicle. When the front wheels are turned, each knuckle moves through an arc that tends to force the tire into the ground. Because this reaction cannot occur, the chassis lifts when the front wheels are turned. When the steering wheel is released after a turn, the vehicle weight has a tendency to settle to its lowest point. Therefore, SAI helps return the wheels to the straight-ahead position after a turn, and also tends to maintain the front wheels in the straight-ahead position. However, SAI does increase steering effort, because the chassis has to lift slightly when cornering.

Front Wheel Toe

Front wheel toe may be defined the same as rear wheel toe. However, the front wheel toe specification usually differs from the rear wheel toe specification. On a rear-wheel-drive car, driving forces tend to move the steering knuckles to a toe-out position. Therefore, these vehicles usually have a slight toe-in. Drive axle forces on a front-wheel-drive vehicle tend to move the front steering knuckles to a toe-in position, and this condition requires a slight toe-out specification.

Scrub Radius

Scrub radius is the distance between the SAI line and the true vertical centerline of the tire at the road surface (Figure 1-38). Scrub radius is determined by the suspension system design, and is not adjustable. Scrub radius does affect steering quality.

Wheel **setback** occurs when one wheel is driven rearward in relation to the opposite wheel.

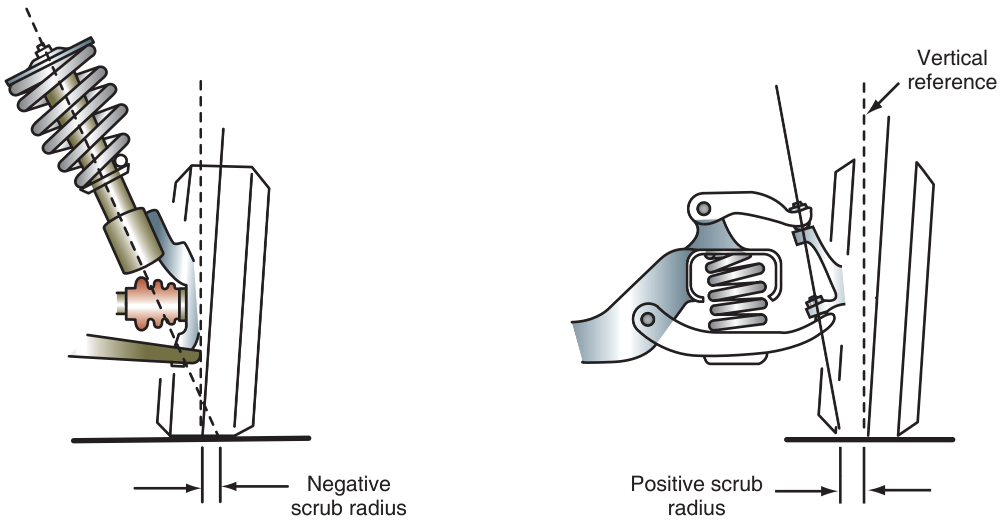

FIGURE 1-38 **Scrub radius.**

Wheel Setback

Wheel **setback** occurs when one wheel is driven rearward in relation to the opposite front wheel (Figure 1-39). Setback may occur on rear wheels, but is most likely to be present on front wheels. Setback is usually caused by collision damage.

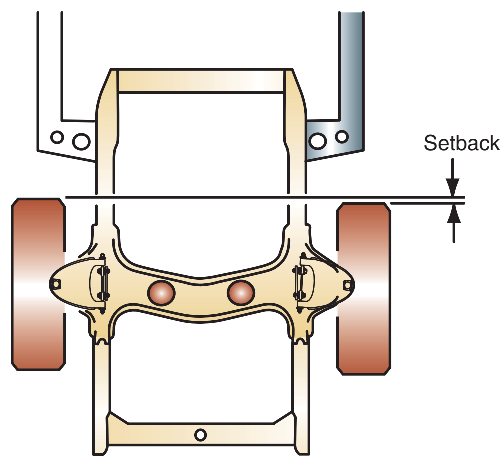

FIGURE 1-39 **Setback.**

A BIT OF HISTORY

China is one of the emerging automotive markets in the world. In 2002 Chinese car sales totaled 1,126,000. This was the first year that car sales in China exceeded 1,000,000, and car sales from 2001 to 2002 increased approximately 50%. Total sales of cars, trucks, and buses totaled 3,500,00 in 2002. In the first 3 months of 2003 car sales increased 40% to 1,360,000. Experts predict that car sales in China may never achieve this rate of growth again, but predict a significant, steady growth rate for the Chinese automotive industry. Some North American vehicle and parts manufacturers are forming partnerships with Chinese automotive manufacturers and building automotive manufacturing facilities in China.

Summary

- The suspension system must provide proper steering control and ride quality.
- The steering system must maintain vehicle safety and reduce driver fatigue.
- All parts of a unitized body are load-carrying members and these parts are welded together to form a strong assembly.
- Carbon dioxide (CO_2) is a by-product of the gasoline, diesel fuel, or ethanol combustion process.
- Greenhouse gasses collect in the earth's upper atmosphere and form a blanket around the earth, which traps heat nearer the earth's surface.
- Front and rear suspension systems must provide proper wheel position, steering control, ride quality, and tire life.
- A short-and-long arm (SLA) front suspension system has a lower control arm that is longer than the upper control arm.
- In a MacPherson strut front suspension system, the top of the steering knuckle is supported by the lower end of the strut.
- Rear suspension systems can be live axle, semi-independent, or independent.
- Wheel rims are manufactured from steel, cast aluminum, forged aluminum, pressure-cast chrome-plated aluminum, or magnesium alloy.
- Wheel hubs contain the wheel bearings and support the load supplied by the vehicle weight.
- Bearing loads can be radial, thrust, or angular.
- Shock absorbers control spring action and wheel oscillations.
- Computer-controlled suspension systems can contain air springs and/or computer-controlled shock absorbers.
- The steering column connects the steering wheel to the steering gear.
- The steering linkage connects the steering gear to the front wheels.
- Steering gears can be recirculating ball or rack-and-pinion type.
- Proper wheel alignment provides steering control, ride quality, and normal tire tread life.
- Improper wheel alignment contributes to steering pull when driving straight ahead, improper steering wheel return, harsh ride quality, rapid tire tread wear, and steering pull while braking.

Terms to Know

Angular bearing load
Carbon dioxide (CO_2)
Green house gas
Included angle
Jounce travel
Negative camber
Negative caster
Negative offset
Negative-phase steering
Positive camber
Positive caster
Positive offset
Positive-phase steering
Radial bearing load
Rebound travel
Scrub radius
Serpentine belt
Setback
Sideslip
Steering axis inclination (SAI)
Thrust bearing load
Thrust line
Toe-out
Turning circle
Wheel alignment
Wheel offset
Wheel shimmy

Review Questions

Short Answer Essays

1. Explain how the engine and transaxle are supported in a front-wheel-drive vehicle with a unitized body.
2. Explain the purpose of coil springs in a short-and-long arm front suspension system.
3. Describe how the top of the steering knuckle is supported in a MacPherson strut front suspension system.
4. Explain the disadvantages of a live axle rear suspension system.
5. Explain the sources of CO_2 related to gasoline production and vehicle operation.
6. Describe the design of a wheel rim with positive offset.
7. Explain a radial bearing load.
8. Describe jounce wheel travel.

9. Explain the operation of a computer-controlled shock absorber that contains magneto-rheological fluid.
10. Explain why CO_2 is a harmful gas.

Fill-in-the-Blanks

1. In a rack and pinion steering gear, the inner ends of the tie rods are attached to the ends of the ______________.
2. Fluid is forced from the power steering pump through a ______________ to the steering gear.
3. In an electronic power steering system, the steering computer receives input signals from the _________ sensor and the ______________ sensor.
4. When turning the vehicle at low speeds, a four-wheel steering system provides a shorter ______________ .
5. Excessive toe-out on a rear wheel may cause _______ and rapid ______________.
6. The vehicle thrust line should be positioned at the ______________ of the vehicle.
7. If a wheel has negative camber, the tire centerline is tilted ______________ in relation to the true vertical tire centerline.
8. After completing a turn, the steering axis inclination (SAI) angle helps to return the front wheels to the ______________ position.
9. If the outside front wheel is turned at a 20° angle, the inside front wheel turning angle should be ______________°.
10. Excessive wheel setback is usually caused by _______ ______________.

Multiple Choice

1. Unitized vehicle bodies have these special features and applications:
   A. Unitized bodies are typically used in large rear-wheel drive vehicles.
   B. Unitized bodies have special steel panels in the hood and trunk lid to protect the vehicle occupants in a collision.
   C. Some members of a unitized body are load-carrying members.
   D. Unitized bodies have a steel box around the passenger compartment.
2. The purpose of the upper and lower control arms in a short-and-long arm front suspension system is to:
   A. Allow the steering knuckle to turn to the right or left.
   B. Control spring action on irregular road surfaces.
   C. Reduce body sway.
   D. Control lateral (side-to-side) wheel movement.
3. A semi-independent rear suspension system has:
   A. A rear axle with an inverted steel U-section containing a tubular stabilizer bar.
   B. Upper and lower control arms.
   C. A one-piece rear axle housing.
   D. A lower ball joint.
4. All of these statements about wheel rims are true EXCEPT:
   A. Wheel rims must position the tires at the proper distance inward or outward from the vertical wheel mounting surface.
   B. A wheel rim with a positive offset has the center of the tire positioned inboard from the vertical wheel mounting surface.
   C. A wheel rim with a neutral offset has the center of the tire positioned at the vertical center of the brake rotor.
   D. A wheel rim with a negative offset has the center of the tire positioned outboard from the vertical wheel mounting surface.
5. A thrust-type bearing load is applied in a:
   A. Horizontal direction.
   B. Vertical direction.
   C. Angular direction.
   D. Radial direction.
6. Shock absorbers control spring action and help to prevent:
   A. Improper wheel and tire position.
   B. Wheel oscillations.
   C. Excessive steering effort.
   D. Slow steering wheel return after a turn.

7. In a parallelogram steering linkage, the tie rods are parallel to the:
   A. Steering arms.
   B. Center link.
   C. Upper control arms.
   D. Lower control arms.
8. All of these statements about recirculating ball steering gears are true EXCEPT:
   A. Ball bearings are mounted between the worm gear and the ball nut.
   B. The lower end of the sector shaft is splined to the idler arm.
   C. As the steering wheel is turned, the ball nut moves upward or downward on the worm gear.
   D. The steering shaft is attached to the worm gear.
9. Excessive rear wheel toe-out on the left rear wheel causes:
   A. Steering pull to the right.
   B. Harsh ride quality.
   C. Reduced steering effort.
   D. Excessive wheel oscillations.
10. When the steering axis inclination (SAI) angle is increased:
    A. The steering wheel return speed is decreased.
    B. The front wheels tend to remain in the straight-ahead position.
    C. The included angle is decreased.
    D. The front wheel toe-in is increased.

Chapter 1

SAFETY

UPON COMPLETION AND REVIEW OF THIS CHAPTER, YOU SHOULD BE ABLE TO:

- Recognize shop hazards and take the necessary steps to avoid personal injury or property damage.
- Describe the general shop rules that must be followed in an automotive shop.
- Explain the purposes of the Occupational Safety and Health Act.
- Explain two reasons why batteries are a shop hazard.
- Describe how long hair may be a shop hazard.
- Explain how incandescent trouble lights may be a shop hazard.
- Describe the harmful effects of carbon monoxide on the human body.
- Explain why asbestos dust in the shop air is a hazard.
- Describe the requirements for the location of safety equipment in the shop.
- Explain four different types of fires, and the fire extinguisher required for each type of fire.
- Describe three pieces of shop safety equipment other than fire extinguishers.
- Describe the main purposes of the Right-to-Know laws.
- Describe the purpose of MSDSs and list the information that must be contained on these sheets.
- Explain the employer's responsibility regarding hazardous materials in the shop.
- Observe all general shop safety precautions.
- Demonstrate all precautions related to personal safety when working in the shop.
- Explain why smoking is dangerous in the shop.
- Explain why drug or alcohol use is dangerous in the shop.
- Describe basic electrical safety precautions.
- Explain gasoline safety precautions.
- Describe housekeeping safety precautions.
- Explain fire safety precautions.
- Describe the proper procedure for using a fire extinguisher.
- Describe the necessary precautions to maintain air bag safety.
- Describe the precautions to be observed when driving vehicles in the shop.
- Explain the proper procedure for lifting heavy objects.
- Describe the necessary steps for hand tool safety.
- Explain the necessary precautions when operating a vehicle lift.
- Describe hydraulic jack and safety stand safety precautions.
- Explain the necessary safety precautions when using power tools.
- Describe the precautions required to maintain compressed-air equipment safety.
- Explain the precautions and environmental concerns related to cleaning equipment safety.

Introduction

Safety is extremely important in the automotive shop! The knowledge and practice of safety precautions prevent serious personal injury and expensive property damage. Automotive students and technicians must be familiar with shop hazards and shop safety rules. The first step in providing a safe shop is learning about shop hazards and safety rules. The second, and most important, step in this process is applying your knowledge of shop hazards and safety rules while working in the shop. In other words, you must develop safe working habits in the shop from your understanding of shop hazards and safety rules. When shop employees have a careless attitude toward safety, accidents are more likely to occur; therefore, all shop personnel must develop a serious attitude toward safety. The result of this attitude is serious shop personnel who will learn and adopt all shop safety rules.

Shop personnel must be familiar with their rights regarding hazardous waste disposal. These rights are explained in the **Right-to-Know laws**. Shop personnel must also be familiar with the types of hazardous materials in the automotive shop and the proper disposal methods for these materials according to state and federal regulations.

Occupational Safety and Health Act

The **Occupational Safety and Health Act (OSHA)** was passed by the U.S. government in 1970. The purposes of this legislation are:

1. to assist and encourage the citizens of the United States in their efforts to ensure safe and healthful working conditions by providing research, information, education, and training in the field of occupational safety and health.
2. to ensure safe and healthful working conditions for working men and women by authorizing enforcement of the standards developed under the Act.

Because approximately 25 percent of workers are exposed to health and safety hazards on the job, the OSHA is necessary to monitor, control, and educate workers regarding health and safety in the workplace.

Shop Hazards

Service technicians and students encounter many hazards in an automotive shop. When these hazards are known, basic shop safety rules and procedures must be followed to avoid personal injury. Some of the hazards in an automotive shop include the following:

1. Flammable liquids, such as gasoline and paint, must be handled and stored properly in approved, closed containers to comply with safety regulations.
2. Flammable materials, such as oily rags, must be stored properly in closed containers to avoid a fire hazard.
3. Batteries contain a corrosive sulfuric acid solution and produce explosive hydrogen gas while charging.
4. Loose sewer and drain covers may cause foot or toe injuries.
5. Caustic liquids, such as those in hot cleaning tanks, are harmful to skin and eyes.
6. High-pressure air in the shop's compressed-air system can be very dangerous or fatal if it penetrates the skin and enters the bloodstream. High-pressure air released near the eyes may cause eye injury.
7. Frayed cords on electrical equipment and lights may result in severe electrical shock.
8. Hazardous waste material, such as batteries and caustic cleaning solutions, must be handled with adequate personal protection to avoid injury (Figure 1-1).
9. Carbon monoxide from vehicle exhaust is poisonous and potentially fatal.
10. Loose clothing or long hair may become entangled in rotating parts on equipment or vehicles, resulting in serious injury.

FIGURE 1-1 **Always wear recommended safety clothing and equipment when handling hazardous materials.**

11. Dust and vapors generated during some repair jobs are harmful. Asbestos dust, which may be released during brake lining service and clutch service, is a contributor to lung cancer.
12. High noise levels from shop equipment such as an air chisel may be harmful to the ears.
13. Oil, grease, water, or parts cleaning solutions on shop floors may cause someone to slip and fall, resulting in serious injury.
14. The incandescent bulbs used in some trouble lights may shatter if the light is dropped, igniting flammable materials in the area and causing a fire. Many insurance companies now require the use of trouble lights with fluorescent bulbs in the shop.

Shop Safety Rules

Applying basic shop rules helps prevent serious, expensive accidents. Failure to comply with shop rules may cause personal injury or expensive damage to vehicles and shop facilities. It is the responsibility of the employer and all shop employees to make sure that shop rules are understood and followed until these rules become automatic habits. The following basic shop rules should be observed:

1. Always wear safety glasses and other protective equipment that is required by a service procedure (Figure 1-2). For example, a brake parts washer must be used to avoid breathing asbestos dust into the lungs. Asbestos dust is a known cause of lung cancer. This dust is encountered in manual transmission clutch facings and brake linings.
2. Tie long hair securely behind your head, and do not wear loose or torn clothing.
3. Do not wear rings, watches, or loose hanging jewelry. If jewelry such as a ring, metal watchband, or chain makes contact between an electrical terminal and ground, the jewelry becomes extremely hot, resulting in severe burns.
4. Do not work in the shop while under the influence of alcohol or drugs.
5. Set the parking brake when working on a vehicle. If the vehicle has an automatic transmission, place the gear selector in park unless a service procedure requires another

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The improper or excessive use of alcohol or drugs may be referred to as substance abuse.

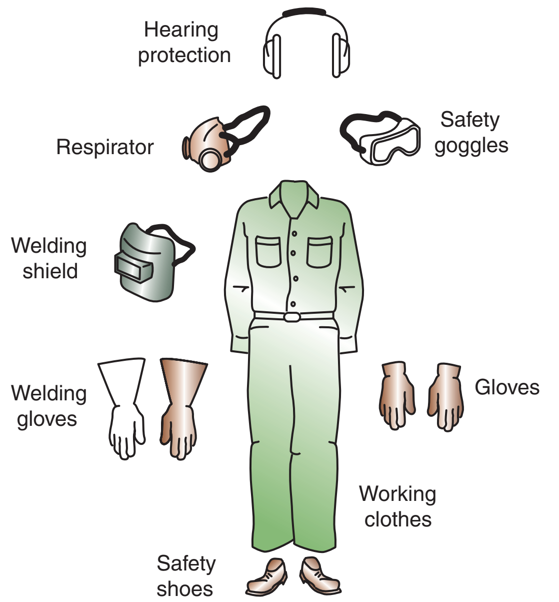

FIGURE 1-2 **Shop safety clothing and equipment, including safety goggles, respirator, welding shield, proper work clothes, ear protection, welding gloves, work gloves, and safety shoes.**

selector position. When the vehicle is equipped with a manual transmission, position the gear selector in neutral with the engine running or in reverse with the engine stopped.

6. Always connect a shop exhaust hose to the vehicle tailpipe, and be sure the shop exhaust fan is running. If it is absolutely necessary to operate a vehicle without a shop exhaust pipe connected to the tailpipe, open the large shop door to provide adequate ventilation. Carbon monoxide in the vehicle exhaust may cause severe headaches and other medical problems. High concentrations of carbon monoxide may result in death!
7. Keep hands, clothing, and wrenches away from rotating parts such as cooling fans. Remember that electric-drive fans may start turning at any time, even with the ignition off.
8. Always leave the ignition switch off unless a service procedure requires another switch position.
9. Always follow the vehicle manufacturer's recommended procedure to disable the high-voltage electrical system and wait for 5 minutes before working on a **hybrid vehicle**. A switch under the steering column is pushed to the Off position to disable the high-voltage system on some hybrid vehicles. On other hybrid vehicles, the high-voltage disconnect switch is mounted at or near the high-voltage battery pack. On some hybrid vehicles, the high-voltage system retains voltage for 5 minutes after the disable switch is turned off.

A hybrid vehicle has a power train with two power sources. The most common type of hybrid vehicle has a gasoline engine and an electric drive motor(s).

10. Do not smoke in the shop. If the shop has designated smoking areas, smoke only in these areas.
11. Store oily rags and other discarded combustibles in covered metal containers designed for this purpose.
12. Always use the wrench or socket that fits properly on the bolt. Do not substitute metric for English wrenches, or vice versa.
13. Keep tools in good condition. For example, do not use a punch or chisel with a mushroomed end because when struck with a hammer, a piece of the mushroomed metal could break off, resulting in severe eye or other injury.

14. Do not leave power tools running and unattended.
15. Serious burns may be prevented by avoiding contact with hot metal components, such as exhaust manifolds and other exhaust system components, radiators, and some air-conditioning hoses.
16. When a lubricant such as engine oil is drained, always wear heavy plastic gloves because the oil could be hot enough to cause burns.
17. Prior to getting under a vehicle, be sure the vehicle is placed securely on safety stands.
18. Operate all shop equipment, including lifts, according to the equipment manufacturer's recommended procedure. Do not operate equipment unless you are familiar with the correct operating procedure.
19. Do not run or engage in horseplay in the shop.
20. Obey all state and federal fire, safety, and environmental regulations.
21. Do not stand in front of or behind vehicles.
22. Always place fender, seat, and floor mat covers on a customer's vehicle before working on the car.
23. Inform the shop foreman of any safety dangers, as well as suggestions for safety improvement.
24. Do not direct high-pressure air from an air gun toward human skin or near the eyes. High-pressure air may penetrate the skin and enter the bloodstream. Air in the bloodstream may be fatal! High-pressure air discharged near the eyes may cause serious eye damage.

Air Quality

Vehicle exhaust contains small amounts of carbon monoxide, which is a poisonous gas. Weak concentrations of carbon monoxide in the shop air may cause nausea and headaches; strong concentrations may be fatal. All shop personnel are responsible for air quality in the shop. Shop management is responsible for providing an adequate exhaust system that can remove exhaust fumes from the maximum-allowable number of vehicles that may be running in the shop at one time. Technicians should never run a vehicle in the shop unless a shop exhaust hose is installed on the tailpipe of the vehicle. The exhaust fan must be switched on to remove exhaust fumes.

If shop heaters or furnaces have restricted chimneys, they release carbon monoxide emissions into the shop air. Therefore, chimneys should be checked periodically for restriction and proper ventilation. Diesel exhaust contains some carbon monoxide, but particulate emissions are also present in the exhaust from these engines. Particulates are small carbon particles that can be harmful to the lungs.

Monitors are available to measure the level of carbon monoxide in the shop. Some of these monitors read the amount of carbon monoxide present in the shop air; others provide an audible alarm if the concentration of carbon monoxide exceeds the danger level.

The sulfuric acid solution in car batteries is a corrosive, poisonous liquid. If a battery is charged with a fast charger at a high rate for a period of time, the battery becomes hot, and the sulfuric acid solution begins to boil. Under this condition, the battery may emit strong sulfuric acid fumes that may be harmful to the lungs. If this happens, the battery charger should be turned off or the charging rate should be reduced considerably.

Some automotive clutch facings and brake linings contain asbestos. Never use an air hose to blow dirt from these components, because this action disperses asbestos dust into the shop where it may be inhaled by technicians and other people in the shop. A brake parts washer or a vacuum cleaner with special attachments must be used to clean the dust from these components. Even though technicians take every precaution to maintain air quality in the shop, some undesirable gases may still get into the air. For example, exhaust manifolds may get oil on them during an engine overhaul. When the engine is started

and these manifolds get hot, the oil burns off the manifolds and pollutes the shop air with oil smoke. Adequate shop ventilation must be provided to take care of this type of air contamination.

Shop Safety Equipment

Fire Extinguishers

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Fire extinguishers are one of the most important pieces of safety equipment. All shop personnel must know the location of each fire extinguisher in the shop. If you have to waste time looking for an extinguisher after a fire starts, the fire could get out of control before you get the extinguisher into operation. Fire extinguishers should be located where they are easily accessible at all times. A decal on each fire extinguisher identifies the type of chemical in the extinguisher and provides operating information (Figure 1-3). Shop personnel should be familiar with the following types of fires and fire extinguishers:

1. *Class A fires* are those involving ordinary combustible materials such as paper, wood, clothing, and textiles. **Multipurpose dry chemical fire extinguishers** are used on these fires.
2. *Class B fires* involve the burning of flammable liquids such as gasoline, oil, paint, solvents, and greases. These fires can also be extinguished with multipurpose dry chemical fire extinguishers. In addition, fire extinguishers containing halogen, or halon, may be used to extinguish class B fires. The chemicals in this type of extinguisher attach to the hydrogen, hydroxide, and oxygen molecules to stop the com bustion process almost instantly. However, the resultant gases from the use of halogen-type extinguishers are very toxic and harmful to the operator of the extinguisher.
3. *Class C fires* involve the burning of electrical equipment such as wires, motors, and switches. These fires can be extinguished with multipurpose dry chemical fire extinguishers.
4. *Class D fires* involve the combustion of metal chips, turnings, and shavings. Dry chemical fire extinguishers are the only type of extinguisher recommended for these fires.

Some multipurpose dry chemical fire extinguishers may be used on Class A, B, C, or D fires. Additional information regarding which types of extinguishers are used for various types of fires is provided in Table 1-1.

FIGURE 1-3 **Types of fire extinguishers.**

TABLE 1-1 **GUIDE TO FIRE EXTINGUISHER SELECTION**

	Class of fire	Typical fuel involved	Type of extinguisher
Class A Fires (green)	**For ordinary combustibles** Put out a class A fire by blowing its temperature or by coating the burning combustibles.	Wood Paper Cloth Rubber Plastics Rubbish Upholstery	Water* Foam* Multipurpose dry chemical
Class B Fires (red)	**For flammable liquids** Put out a class B fire by smothering it. Use an extinguisher that gives a blanketing, flame-interrupting effect; cover whole flaming liquid surface.	Gasoline Oil Grease Paint Lighter fluid	Foam* Carbon dioxide Halogenated agent Standard dry chemical Purple K dry chemical Multipurpose dry chemical
Class C Fires (blue)	**For electrical equipment** Put out a class C fire by shutting off power as quickly as possible and by always using a nonconducting extinguisher agent to prevent electric snock.	Motors Appliances Wiring Fuse boxes Switchboards	Carbon dioxide Halogenated agent Standard dry chemical Purple K dry chemical Multipurpose dry chemical
Class D Fires (yellow)	**For combustible metals** Put out a class D fire o metal chips, turnings, or shavings by smothering or coating with a specially designed extinguisher agent.	Aluminum Magnesium Potassium Sodium Titanium Zirconium	Dry power extinguisher and agents only

*Cartridge-operated water, foam, and soda-acid types of extinguishers are no longer manufactured. These extinguishers should be removed from service when they become due for their next hydrostatic pressure test.

Causes of Eye Injuries

Eye injuries can occur in various ways in the automotive shop. Some of the more common eye accidents are:

1. Thermal burns from excessive heat
2. Irradiation burns from excessive light such as from an arc welder
3. Chemical burns from strong liquids such as battery electrolyte
4. Foreign material in the eye
5. Penetration of the eye by a sharp object
6. A blow from a blunt object

Wearing safety glasses and observing shop safety rules will prevent most eye accidents.

Eyewash Fountains

If a chemical gets in your eyes, it must be washed out immediately to prevent a chemical burn. An eyewash fountain is the most effective way to wash the eyes. An eyewash fountain is similar to a drinking water fountain, but the eyewash fountain has water jets placed throughout the fountain top. Every shop should be equipped with some type of eyewash facility (Figure 1-4). Be sure you know the location of the eyewash fountain in the shop.

Safety Glasses and Face Shields

The mandatory use of eye protection, either safety glasses or a face shield, is one of the most important safety rules in an automotive shop. Face shields protect the face; safety glasses

FIGURE 1-4 Eyewash fountain.

FIGURE 1-5 Safety glasses with side protection must be worn in the automotive shop.

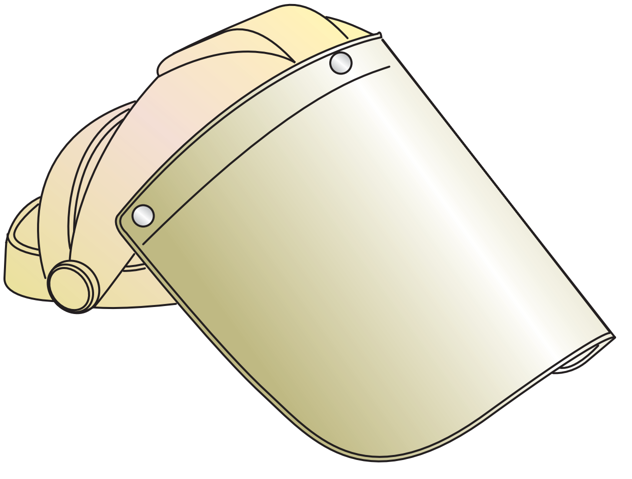

FIGURE 1-6 Face shield.

protect the eyes. When grinding, safety glasses must be worn, and a face shield can be worn. Many shop insurance policies require the use of eye protection in the shop. Some automotive technicians have been blinded in one or both eyes because they did not wear safety glasses. All safety glasses must be equipped with safety glass and should provide some type of side protection (Figure 1-5). Whenselecting a pair of safety glasses, they should feel comfortable on your face because if they are uncomfortable, you may remove them, leaving your eyes unprotected. A face shield should be worn when handling hazardous chemicals or when using an electric grinder or buffer (Figure 1-6).

First-Aid Kits

First-aid kits should be clearly identified and conveniently located (Figure 1-7). These kits contain such items as bandages in a variety of sizes and ointment required for minor cuts. All shop personnel must be familiar with the location of first-aid kits. At least one of the

FIGURE 1-7 **First-aid kit.**

shop personnel should have basic first-aid training. This person should be in charge of administering first aid and keeping first-aid kits filled.

Shop Layout

There are many different types of shops in the automotive service industry, including:

- New car dealers
- Independent repair shops
- Specialty shops
- Service stations
- Fleet shops

In any shop, the layout is important to maintain shop efficiency and contribute to safety. Every shop employee must be familiar with the location of all safety equipment in the shop. Shop layout includes bays for various types of repairs, equipment storage areas, and office locations. Some specific types of bays are electrical repair, wheel alignment and tires, and machining bays (Figure 1-8). Safety equipment such as fire extinguishers, first-aid kits, and eyewash fountains must be in easily accessible locations, and the location of each piece of safety equipment must be clearly marked. Areas such as the parts department and the parts cleaning area must be located so they are easily accessible from all areas of the shop. The service manager's office should also be centrally located. All shop personnel should familiarize themselves with the shop layout, especially the location of safety equipment. If you know the exact fire extinguisher locations, you may get an extinguisher into operation a few seconds faster. Those few seconds could make the difference between a fire that is quickly extinguished and one that gets out of control, causing extensive damage and personal injury!

The tools and equipment required for a certain type of work are stored in that specific bay. For example, the equipment for electrical and electronic service work is stored in the bay allotted to that type of repair. When certain bays are allotted to specific types of repair work, unnecessary equipment movement is eliminated. Each technician has his or her own tools on a portable roll cabinet that is moved to the vehicle being repaired. Special tools are provided by the shop, and these tools should be located on tool boards attached to the wall. Other shops may have a tool room where special tools are located. Adequate workbench space must be provided in those bays where bench work is required.

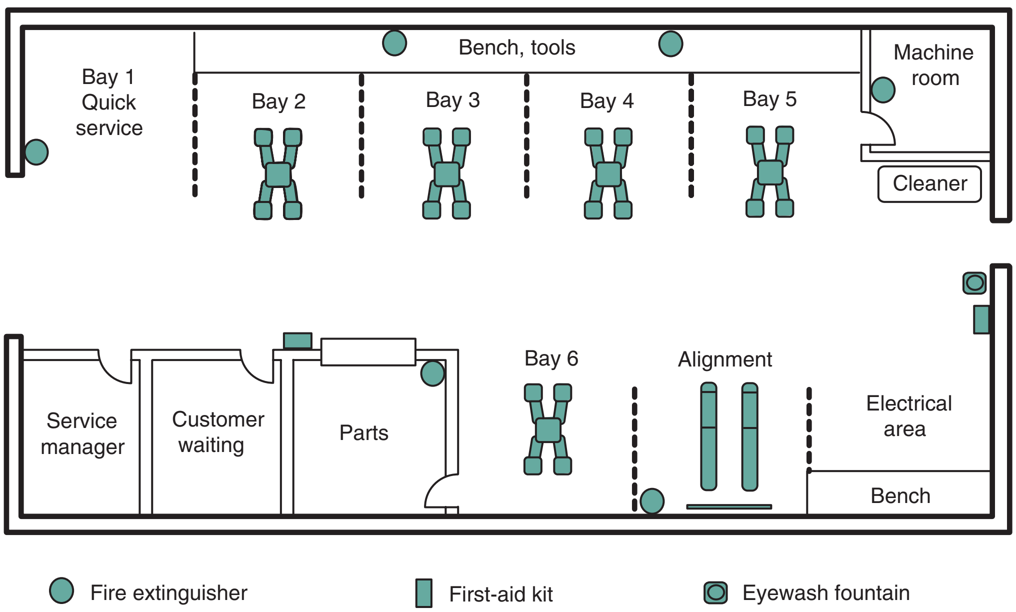

FIGURE 1-8 **Shop layout.**

Safety in the Automotive Shop

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Each person in an automotive shop must follow certain basic shop safety rules to remove the danger from shop hazards and prevent personal injury, vehicle damage, and property damage.

Technicians must understand shop safety as it applies to these categories:

1. General shop safety
2. Personal safety

General Shop Safety

A **brake parts washer** is used to wash brake or clutch components and to prevent asbestos particles from becoming airborne and entering the technician's lungs.

When general shop safety rules are observed, personal injury and expensive property or vehicle damage may be avoided, and shop production is increased.

1. All sewer covers must fit properly and be kept securely in place.
2. When servicing brakes or clutches from manual transmissions, always clean asbestos dust from these components with an OSHA-approved **brake parts washer** (Figure 1-9). The brake parts washer contains a Greasoff® brake cleaning solution. The washer is placed under the wheel brake assembly to be washed, and a pump in the washer forces the cleaning solution through a hose and brush that is used to clean the brake components. Removed brake components may also be washed in the top tray on the washer.

WARNING: Do not breathe asbestos dust, because this dust is a known contributor to lung cancer.

3. Always use the correct tool for the job. For example, never strike a hardened steel component, such as a piston pin, with a steel hammer. This type of component may shatter, and fragments can penetrate eyes or skin.
4. Follow the car manufacturer's recommended service procedures.
5. Avoid working on a vehicle parked on an incline.
6. Never work under a vehicle unless the vehicle chassis is supported securely on safety stands.

FIGURE 1-9 **Brake parts cleaner.**

7. When one end of a vehicle is raised, place wheel chocks on both sides of the wheels remaining on the floor.
8. Be sure that you know the location of shop first-aid kits, eyewash fountains, and fire extinguishers.
9. Collect oil, fuel, brake fluid, and other liquids in the proper safety containers.
10. Use only approved cleaning fluids and equipment. Do not use gasoline to clean parts.
11. Do not leave running equipment unattended.
12. Be sure the safety shields are in place on rotating equipment.
13. All shop equipment must have regularly scheduled maintenance and adjustment.
14. Some shops have safety lines around equipment. Always work within these lines when operating equipment.
15. Be sure that shop heating equipment is well-ventilated.
16. Do not run in the shop or engage in horseplay.
17. Post emergency phone numbers near the phone. These numbers should include doctor, ambulance, fire department, hospital, and police.
18. Do not place hydraulic jack handles where someone can trip over them.
19. Keep aisles clear of debris.

Personal Safety

Personal safety is the responsibility of each technician in the shop.

Always follow these safety practices:

1. Always use the correct tool for the job. If the wrong tool is used, it may slip and cause injury.
2. Follow the vehicle manufacturer's recommended service procedures.
3. Always wear eye protection, such as safety glasses with side protection or a face shield.
4. Wear protective gloves when cleaning parts in hot or cold tanks and when handling hot parts, such as exhaust manifolds.
5. Always wear 1,000 V, class-0 rated, high-voltage gloves to protect against electrical shock when servicing hybrid vehicles.
6. Regularly inspect high-voltage gloves for pin holes or other damage that could result in electric shock. Replace high-voltage gloves at the glove manufacturer's recommended intervals.

7. Before working on a hybrid vehicle, always follow the vehicle manufacturer's recommended service procedure to disable the high-voltage electrical system. On many hybrid vehicles, the high-voltage disconnect switch is located at or near the high-voltage battery pack. Turn the high-voltage disconnect switch Off to disable the high-voltage system.
8. After the high-voltage system is disabled on a hybrid vehicle, always wait for the time period specified by the vehicle manufacturer before servicing the vehicle. On some hybrid vehicles, the high-voltage system retains voltage for 5 minutes after the disable switch is turned off.
9. Some hybrid vehicles contain nickel–metal hydride batteries in the high-voltage battery pack. These batteries contain potassium hydroxide, a highly alkaline solution that damages human tissue. Always follow the vehicle manufacturer's recommended service procedures and wear the recommended protective equipment such as a face shield and gloves when servicing these batteries.
10. Do not smoke when working in the shop. A spark from a cigarette or lighter may ignite flammable materials in the work area.
11. When working on a running engine, keep hands and tools away from rotating parts. Remember that electric-drive fans may start turning at any time.
12. Do not wear loose clothing, and keep long hair tied behind your head. Loose clothing or long hair is easily entangled in rotating parts.
13. Wear safety shoes or boots. Heavy-duty work boots or shoes with steel toe caps are best for working in the automotive shop. Footwear must protect against heavy falling objects, flying sparks, and corrosive liquids. Soles on footwear must protect against punctures by sharp objects. Athletic shoes and street shoes are not recommended in the shop.
14. Be sure that the shop has adequate ventilation. Carbon monoxide is odorless; do not expect to be able to smell it.
15. Make sure the work area has adequate lighting.
16. When servicing a vehicle, always apply the parking brake. Place the transmission in park with an automatic transmission, or neutral with a manual transmission.
17. Avoid working on a vehicle parked on an incline.
18. Never work under a vehicle unless the vehicle chassis is supported securely on safety stands.
19. Do not use electrical equipment, including trouble lights, with frayed cords.
20. Be sure the safety shields are in place on rotating equipment.
21. Before operating electric equipment, be sure the power cord has a ground connection.
22. When working in an area where noise levels are extreme, wear earplugs or ear covers.
23. Wear a respirator to protect your lungs when working in dusty conditions.
24. Do not use **incandescent bulb-type trouble lights**. Use **fluorescent trouble lights** (Figure 1-10).

Smoking, Alcohol, and Drugs in the Shop

Do not smoke when working in the shop. If the shop has designated smoking areas, smoke only in these areas. Do not smoke in customers' cars. A nonsmoker will not appreciate cigarette odor in the car. A spark from a cigarette or lighter may ignite flammable materials in the workplace. The use of drugs or alcohol must be avoided while working in the shop. Even a small amount of drugs or alcohol affects reaction time. In an emergency situation, slow reaction time may cause personal injury. If a heavy object falls off the workbench, and your reaction time is slowed by drugs or alcohol, you may not get your foot out of the way in time to avoid a foot injury. When a fire starts in the workplace, and you are a few seconds slower getting a fire extinguisher into operation because of alcohol or drug use, it could make the difference between extinguishing a fire and having expensive fire damage.

The improper or excessive use of alcoholic beverages, inhalants, and/or drugs may be referred to as substance abuse.

FIGURE 1-10 **Incandescent-type trouble light and fluorescent-type trouble light.**

Electrical Safety

In the automotive shop you will be using electric drills, shop lights, wheel balancers, and wheel aligners.

Observe the following electrical safety precautions on this equipment:

1. Frayed cords on electrical equipment must be replaced or repaired immediately.
2. All electrical cords from lights and electrical equipment must have a ground connection. The ground connector is the round terminal in a three-pronged electrical plug. Do not use a two-pronged adapter to plug in a three-pronged electrical cord. Three-pronged electrical outlets should be mandatory in all shops.
3. Do not leave electrical equipment running and unattended.

Gasoline Safety

Gasoline is a very explosive liquid! One exploding gallon of gasoline has a force equal to 14 sticks of dynamite. The expanding vapors from gasoline are extremely dangerous. These vapors are present even in cold temperatures. Vapors formed in gasoline tanks on cars are controlled, but vapors from a gasoline storage can may escape from the can, resulting in a hazardous situation. Therefore, gasoline storage containers must be placed in a well-ventilated space.

Approved gasoline storage cans have a flash-arresting screen at the outlet (Figure 1-11). This screen prevents external ignition sources from igniting the gasoline within the can while the gasoline is being poured.

Follow these safety precautions regarding gasoline containers:

1. Always use approved gasoline containers that are painted red for proper identification.
2. Do not fill gasoline containers completely full. Always leave the level of gasoline at least one inch from the top of the container. This allows for expansion of the gasoline at higher temperatures. If gasoline containers are completely full, the gasoline will expand when the temperature increases. This expansion forces gasoline from the can and creates a dangerous spill.
3. If gasoline containers must be stored, place them in a well-ventilated area such asa storage shed. Do not store gasoline containers in your home or in the trunk of a vehicle.

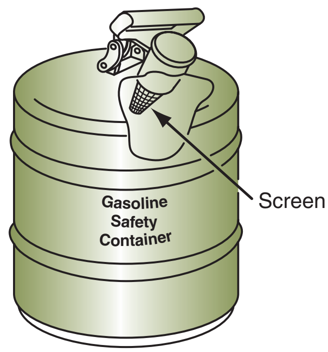

FIGURE 1-11 **Approved gasoline container.**

A gasoline can may be called a jerry can.

4. When a gasoline container must be transported, be sure it is secured against upsets.
5. Do not store a partially filled gasoline container for long periods of time, because it may give off vapors and produce a potential danger.
6. Never leave gasoline containers open except while filling or pouring gasoline from the container.
7. Do not prime an engine with gasoline while cranking the engine.
8. Never use gasoline as a cleaning agent.

Fire Safety

When fire safety rules are observed, personal injury and expensive fire damage to vehicles and property may be avoided. Follow these fire safety rules:

1. Familiarize yourself with the location and operation of all shop fire extinguishers.
2. If a fire extinguisher is used, report it to management so the extinguisher can be recharged.
3. Do not use any type of open-flame heater to heat the work area.
4. Do not turn on the ignition switch or crank the engine with a gasoline line disconnected.
5. Store all combustible materials such as gasoline, paint, and oily rags in approved safety containers.
6. Clean up gasoline, oil, or grease spills immediately.
7. Always wear clean shop clothes. Do not wear oil-soaked clothes.
8. Do not allow sparks and flames near batteries.
9. Be sure that welding tanks are securely fastened in an upright position.
10. Do not block doors, stairways, or exits.
11. Do not smoke when working on vehicles.
12. Do not smoke or create sparks near flammable materials or liquids.
13. Store combustible shop supplies such as paint in a closed steel cabinet.
14. Store gasoline in approved safety containers.
15. If a gasoline tank is removed from a vehicle, do not drag the tank on the shop floor.
16. Know the approved fire escape route from your classroom or shop to the outside of the building.
17. If a fire occurs, do not open doors or windows. This action creates extra draft, which makes the fire worse.
18. Do not put water on a gasoline fire, because the water will make the fire worse.
19. Call the fire department as soon as a fire begins, and then attempt to extinguish the fire.
20. If possible, stand 6 to 10 feet from the fire and aim the fire extinguisher nozzle at the base of the fire with a sweeping action.
21. If a fire produces a lot of smoke in the room, remain close to the floor to obtain oxygen and avoid breathing smoke.
22. If the fire is too hot or the smoke makes breathing difficult, get out of the building.

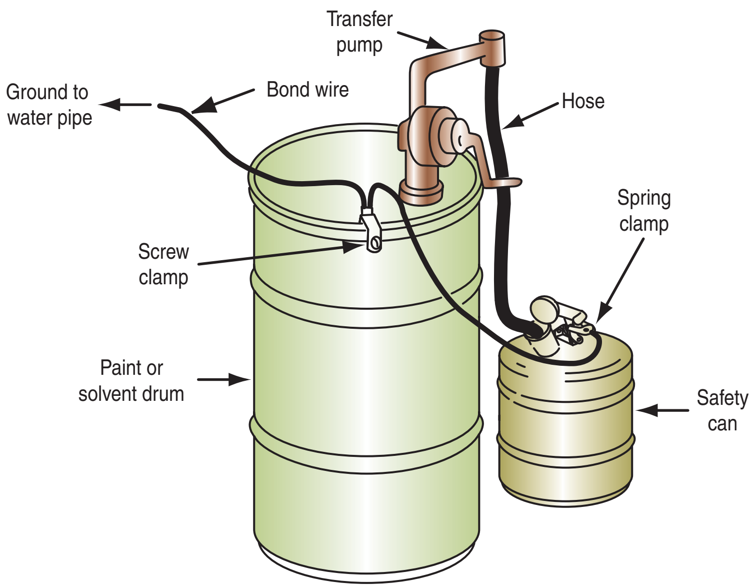

FIGURE 1-12 **Safe procedures for flammable liquid transfer.**

23. Do not re-enter a burning building.
24. Keep solvent containers covered except when pouring from one container to another. When flammable liquids are transferred from bulk storage, the bulk container should be grounded to a permanent shop fixture, such as a metal pipe. During this transfer process, the bulk container should be grounded to the portable container (Figure 1-12). These ground wires prevent the buildup of a static electric charge, which could cause a spark and a disastrous explosion. Always discard or clean empty solvent containers, because fumes in these containers are a fire hazard.
25. Familiarize yourself with different types of fires and fire extinguishers, and know the type of extinguisher to use on each type of fire.

Using a Fire Extinguisher

Everyone working in the shop must know how to operate the fire extinguishers.

There are several different types of fire extinguishers, but their operation usually involves the following steps:

1. Get as close as possible to the fire without jeopardizing your safety.
2. Grasp the extinguisher firmly and aim the extinguisher at the fire.
3. Pull the pin from the extinguisher handle.
4. Squeeze the handle to dispense the contents of the extinguisher.
5. Direct the fire extinguisher nozzle at the base of the fire, and dispense the contents of the extinguisher with a sweeping action back and forth across the fire. Most extinguishers discharge their contents in 8 to 25 seconds.
6. Always be sure the fire is extinguished.
7. Always keep an escape route open behind you so a quick exit is possible if the fire gets out of control.

Vehicle Operation

When driving a customer's vehicle, observe the following precautions to prevent accidents and maintain good customer relations:

1. Prior to driving a vehicle, make sure the brakes are operating and fasten the safety belt.
2. Before you start the engine, check to be sure there is no person or object under the car.

3. If the vehicle is parked on a lift, be sure the lift is fully down and that the lift arms or components are not in contact with the vehicle chassis.
4. Before driving away, check to see if any objects are directly in front of or behind the vehicle.
5. Always drive slowly in the shop, and watch carefully for personnel and other moving vehicles.
6. Make sure the shop door is up high enough so there is plenty of clearance between the top of the vehicle and the door.
7. Watch the shop door to be certain that it is not coming down as you attempt to drive under the door.
8. If a road test is necessary, wear your seat belt, obey all traffic laws, and never drive in a reckless manner.
9. Do not squeal tires when accelerating or turning corners.

If customers observe that service personnel take good care of their car by driving carefully and by installing fender, seat, and floor mat covers, the service department's image is greatly enhanced in their eyes. These procedures impress upon the customers that shop personnel respect their car. Conversely, if grease spots are found on the upholstery or fenders after service work is completed, the customers will probably think the shop is careless, not only in car care but also in service work quality.

Housekeeping Safety

CUSTOMER CARE: When customers see that you are concerned about their vehicle and that you operate a shop with excellent housekeeping habits, they will be impressed and will likely keep returning for service.

Careful housekeeping habits prevent accidents and increase worker efficiency. Good housekeeping also helps impress upon the customer that quality work is a priority in this shop.

Follow these housekeeping rules:

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1. Keep aisles and walkways clear of tools, equipment, and other items.
2. Be sure all sewer covers are securely in place.
3. Keep floor surfaces free of oil, grease, water, and loose material.
4. Sweep up under a vehicle before lowering the vehicle on the lift.
5. Proper trash containers must be conveniently located, and these containers should be emptied regularly.
6. Access to fire extinguishers must be unobstructed at all times, and fire extinguishers should be checked for proper charge at regular intervals.
7. Tools must be kept clean and in good condition.
8. When not in use, tools must be stored in their proper location.
9. Oily rags must be stored in approved, covered containers (Figure 1-13). A slow generation of heat occurs from the oxidation of oil on these rags. Heat may continue to be generated until the ignition temperature is reached. The oil and rags then begin to burn, causing a fire. This action is called spontaneous combustion. However, if the oily rags are in an airtight, approved container, there is not enough oxygen to cause burning.
10. Store paint, gasoline, and other flammable liquids in a closed steel cabinet (Figure 1-14).
11. Rotating components on equipment and machinery must have guards, and all shop equipment should have regular service and adjustment schedules.
12. Keep the workbenches clean. Do not leave heavy objects, such as used parts, on the bench after you are finished with them.
13. Keep parts and materials in their proper location.

SERVICE TIP: When you are finished with a tool, never set it on the customer's car. After using a tool, the best place for it is in your tool box or on the workbench. Many tools have been lost by leaving them on customers' vehicles.

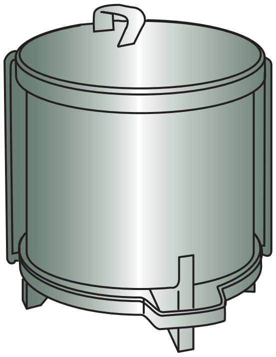


FIGURE 1-13 **Dirty shop towels or rags must be kept in an approved, closed container.**

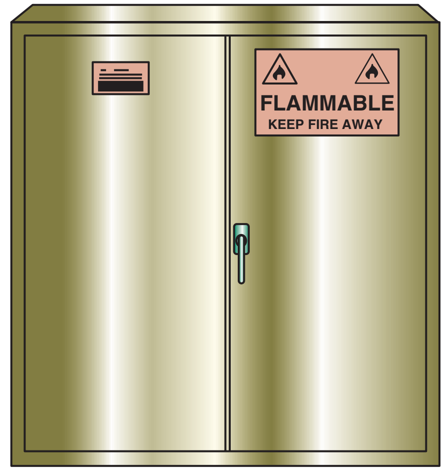


FIGURE 1-14 **Store combustible materials in an approved safety cabinet.**

14. When not in use, creepers must not be left on the shop floor. Creepers should be stored in a specific location.
15. The shop should be well-lit, and all lights should be in working order.
16. Frayed electrical cords on lights or equipment must be replaced.
17. Walls and windows should be cleaned regularly.
18. Stairs must be clean, well-lit, and free of loose material.

Air Bag Safety

1. When service is performed on any **air bag system** component, always disconnect the negative battery cable, isolate the cable end, and wait for the amount of time specified by the vehicle manufacturer before proceeding with the necessary diagnosis or service. The average waiting period is two minutes, but some vehicle manufacturers specify up to ten minutes. Photo Sequence 1 shows a typical procedure for removing an air bag module.

   On some recent-model vehicles, the air bag system is divided into different disabling and enabling zones for diagnostic and service purposes. When performing vehicle service on or near air bag system components, the vehicle manufacturer recommends disabling the air bag components, in the zone where the air bag components are located rather than disconnecting the vehicle battery (Figure 1-15). The air bag system components in each disabling zone are the following:

   Zone 1–Front end air bag sensors
   Zone 2–Driver/side impact sensor

An **air bag system** is designed to protect the driver and/or passengers in a vehicle collision.

SERVICE TIP:
After disconnecting battery voltage from an air bag system, failure to wait for the specified time period before servicing the system may cause accidental air bag deployment.

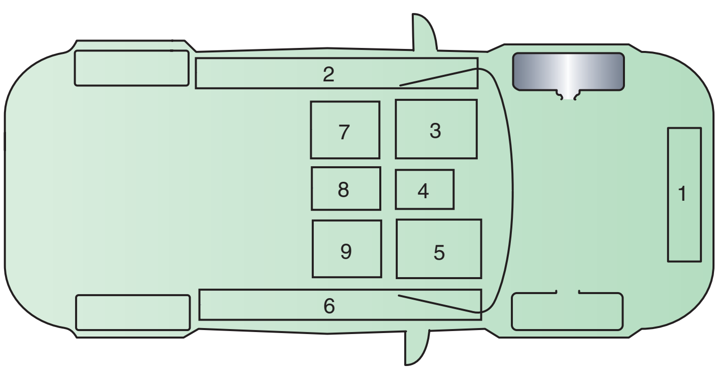


FIGURE 1-15 **Air bag system disabling and enabling zones.**

PHOTO SEQUENCE 1

TYPICAL PROCEDURE FOR REMOVING AIR BAG MODULE

P1-1 **Tools required to remove the air bag module: safety glasses, seat covers, screwdriver set, torx driver set, battery terminal pullers, battery pliers, assorted wrenches, ratchet and socket set, and service manual.**

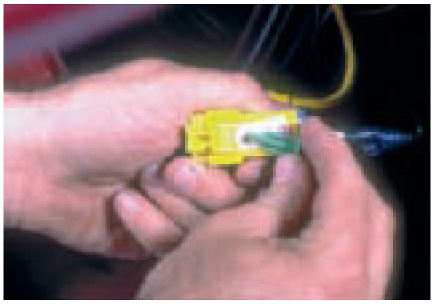
P1-2 **Place the seat and fender covers on the vehicle.**

P1-3 **Place the front wheels in the straight-ahead position, and turn the ignition switch to the LOCK position.**

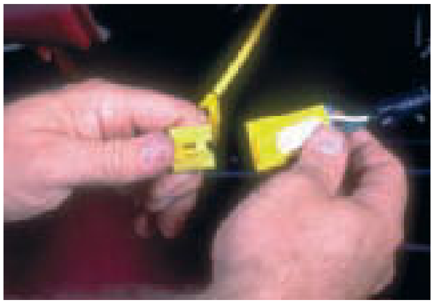
P1-4 **Disconnect the negative battery cable.**

P1-5 **Tape the cable terminal to prevent accidental connection with the battery post. Note: A piece of rubber hose can be substituted for the tape.**

P1-6 **Remove the SIR fuse from the fuse box. Wait 10 minutes to allow the reserve energy to dissipate.**



P1-7 **Remove the connector position assurance (CPA) from the yellow electrical connector at the base of the steering column.**



P1-8 **Disconnect the yellow two-way electrical connector.**

P1-9 **Remove the four bolts that secure the module from the rear of the steering wheel.**

P1-10 **Rotate the horn lead 1/4 turn and disconnect.**

P1-11 **Disconnect the electrical connectors.**

P1-12 **Remove the module.**

Zone 3–Steering wheel air bag inflator module and coil
Zone 4–Air bag system sensing and diagnostic module (SDM)
Zone 5–Air bag system instrument panel module
Zone 6–Passenger/side impact sensor
Zone 7–Driver seat with L/F side impact module and seat belt pretensioner
Zone 8–Not used
Zone 9–Passenger seat with R/F side impact module and seat belt pretensioner

2. Replacement air bag system parts must have the same part number as the original part. Replacement parts of lesser or questionable quality must not be used. Improper or inferior components may result in inappropriate air bag deployment and injury to the vehicle occupants.
3. Do not strike or jar a sensor or an air bag system diagnostic monitor (ASDM). This may cause air bag deployment or make the sensor inoperative. Accidental air bag deployment may cause personal injury, and an inoperative sensor may result in air bag deployment failure, causing personal injury to vehicle occupants.
4. All sensors and mounting brackets must be properly torqued to ensure correct sensor operation before an air bag system is powered up. If sensor fasteners do not have the proper torque, improper air bag deployment may result in injury to vehicle occupants.
5. When working on the electrical system on an air-bag-equipped vehicle, use only the vehicle manufacturer's recommended tools and service procedures. The use of improper tools or service procedures may cause accidental air bag deployment and personal injury. For example, do not use 12 V or self-powered test lights when servicing the electrical system on an air-bag-equipped vehicle.
6. When handling a deployed air bag always wear safety glasses and shop gloves. Dispose of the deployed air bag through the normal refuse channels. Remove the shop gloves and wash your hands in mild soap and water.

WARNING: A deployed air bag may be partially covered with sodium hydroxide, which is a skin and eye irritant.

Lifting and Carrying

Many automotive service jobs require heavy lifting. Know your maximum weight-lifting ability, and do not attempt to lift more than this weight. If a heavy part exceeds your weight-lifting ability, have a coworker help with the lifting job.

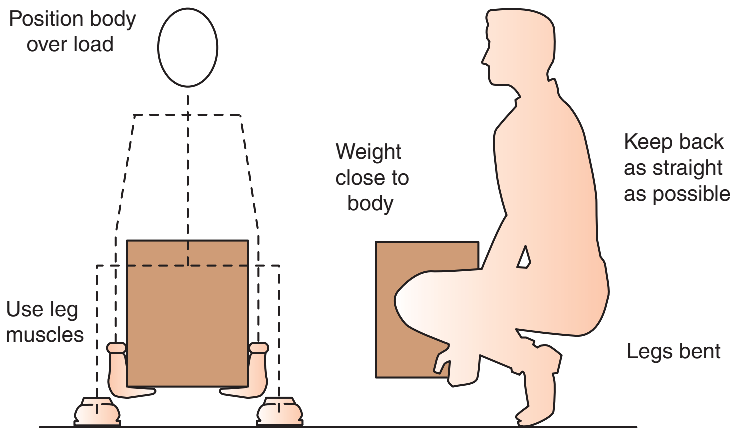


FIGURE 1-16 **Use your leg muscles, never your back, to lift heavy objects.**

Follow these steps when lifting or carrying an object:

1. If the object is going to be carried, be sure your path is free from loose parts or tools.
2. Position your feet close to the object; position your back reasonably straight for proper balance.
3. Your back and elbows should be kept as straight as possible. Continue to bend your knees until your hands reach the best lifting location on the object.
4. Be certain the container is in good condition. If a container falls apart during the lifting operation, parts may drop out of the container and result in foot injury or part damage.
5. Maintain a firm grip on the object; do not attempt to change your grip while lifting is in progress.
6. Straighten your legs to lift the object and keep the object close to your body. Use your leg muscles rather than your back muscles (Figure 1-16).
7. If you have to change the direction of travel, turn your whole body. Do not twist.
8. Do not bend forward to place an object on a workbench or table. Position the object on the front surface of the workbench and slide it back. Do not pinch your fingers under the object while setting it on the front of the bench.
9. If the object must be placed on the floor or a low surface, bend your legs to lower the object. Do not bend your back forward, because this movement strains back muscles.
10. When a heavy object must be placed on the floor, place suitable blocks under the object to prevent jamming your fingers.

Hand Tool Safety

Many shop accidents are caused by improper use and care of hand tools.

Follow these safety steps when working with hand tools:

1. Maintain tools in good condition and keep them clean. Worn tools may slip and result in hand injury. If a hammer with a loose head is used, the head may fly off and cause personal injury or vehicle damage. If your hand slips off a greasy tool, it may cause some part of your body to hit the vehicle, causing injury.
2. Using the wrong tool for the job may damage the tool, fastener, or your hand if the tool slips. If you use a screwdriver as a chisel or pry bar, the blade may shatter, causing serious personal injury.
3. Use sharp-pointed tools with caution. Always check your pockets before sitting on the vehicle seat. A screwdriver, punch, or chisel in the back pocket may put an expensive tear in the upholstery. Do not lean over fenders with sharp tools in your pockets.
4. Tools that are intended to be sharp should be kept sharp. A sharp chisel, for example, will do the job faster with less effort.

Lift Safety

Special precautions and procedures must be followed when a vehicle is raised on a lift.

Follow these steps for safe lift operation:

1. Always be sure the lift is completely lowered before driving a vehicle on or off the lift.
2. Do not hit or run over lift arms and adaptors when driving a vehicle on or off the lift. Have a coworker guide you when driving a vehicle onto the lift. Do not stand in front of a lift with the car coming toward you.
3. Be sure the lift pads contact the car manufacturer's recommended lifting points shown in the service manual. If the proper lifting points are not used, components under the vehicle such as brake lines or body parts may be damaged. Failure to use the recommended lifting points may cause the vehicle to slip off the lift, resulting in severe vehicle damage and personal injury.
4. Before a vehicle is raised or lowered, close the doors, hood, and trunk lid.
5. When a vehicle has been lifted a short distance off the floor, stop the lift and check the contact between the hoist lift pads and the vehicle to be sure the lift pads are still on the recommended lifting points.
6. When a vehicle has been raised, be sure the safety mechanism is in place to prevent the lift from dropping accidentally.
7. Prior to lowering a vehicle, always make sure there are no objects, tools, or people under the vehicle.
8. Do not rock a vehicle on a lift during a service job.
9. When a vehicle is raised, removal of some heavy components may cause vehicle imbalance. For example, because front-wheel-drive cars have the engine and transaxle at the front of the vehicle, these cars have most of their weight on the front end. Removing a heavy rear-end component on these cars may cause the back end of the car to rise off the lift. If this happens, the vehicle could fall off the lift!
10. Do not raise a vehicle on a lift with people in the vehicle.
11. When raising pickup trucks and vans on a lift, remember these vehicles are higher than a passenger car. Be sure there is adequate clearance between the top of the vehicle and the shop ceiling or components under the ceiling.
12. Do not raise a four-wheel drive vehicle with a frame contact lift unless proper adaptors are used. Lifting a vehicle on a frame contact lift without the proper adaptors may damage axle joints.
13. Do not operate a front-wheel drive vehicle that is raised on a frame contact lift. This may damage the front drive axles.

CAUTION:
When a vehicle is raised on a lift, the vehicle must be raised high enough to allow engagement of the lift locking mechanism.

Hydraulic Jack and Safety Stand Safety

WARNING: Always make sure the safety stand weight capacity rating exceeds the vehicle weight that you are planning to raise. A safety stand with insufficient weight capacity may collapse, resulting in vehicle damage and/or personal injury.

WARNING: Never lift a vehicle with a floor jack if the weight of the vehicle exceeds the rated capacity of the jack. If the vehicle weight exceeds the weight rating of the floor jack, the vehicle weight may collapse the floor jack, resulting in jack and vehicle damage and/or personal injury.

Accidents involving the use of floor jacks and safety stands may be avoided if these safety precautions are followed:

1. Never work under a vehicle unless safety stands are placed securely under the vehicle chassis and the vehicle is resting on these stands (Figure 1-17).

FIGURE 1-17 **Safety stands.**

2. Prior to lifting a vehicle with a floor jack, be sure that the jack lift pad is positioned securely under a recommended lifting point on the vehicle. Lifting the front end of a vehicle with the jack placed under a radiator support may cause severe damage to the radiator and support.
3. Position the safety stands under a strong chassis member such as the frame or axle housing. The safety stands must contact the vehicle manufacturer's recommended lifting points.
4. Because the floor jack is on wheels, the vehicle and safety stands tend to move as the vehicle is lowered from a floor jack onto the safety stands. Always be sure the safety stands remain under the chassis member during this operation, and be sure the safety stands do not tip. All the safety stand legs must remain in contact with the shop floor.
5. When the vehicle is lowered from the floor jack onto the safety stands, remove the floor jack from under the vehicle. Never leave a jack handle sticking out from under a vehicle, which may trip someone and cause an injury.

Power Tool Safety

Power tools use electricity, shop air, or hydraulic pressure as a power source. Careless operation of power tools may cause personal injury or vehicle damage.

Follow these steps for safe power tool operation:

1. Do not operate power tools with frayed electrical cords.
2. Be sure the power tool cord has a proper ground connection.
3. Do not stand on a wet floor while operating an electric power tool.
4. Always unplug an electric power tool before servicing the tool.
5. Do not leave a power tool running and unattended.
6. When using a power tool on small parts, do not hold the part in your hand. The part must be secured in a bench vise or with locking pliers.
7. Do not use a power tool on a job where the maximum capacity of the tool is exceeded.
8. Be sure that all power tools are in good condition; always operate these tools according to the tool manufacturer's recommended procedure.
9. Make sure all protective shields and guards are in position.
10. Maintain proper body balance while using a power tool.
11. Always wear safety glasses or a face shield.
12. Wear ear protection.
13. Follow the equipment manufacturer's recommended maintenance schedule for all shop equipment.
14. Never operate a power tool unless you are familiar with the tool manufacturer's recommended operating procedure, because serious accidents can occur.
15. Always make sure that the wheels are securely attached and in good condition on the electric grinder.

16. Keep fingers and clothing away from grinding and buffing wheels. When grinding or buffing a small part, hold the part with a pair of locking pliers.
17. Always make sure the sanding or buffing disc is securely attached to the sander pad.
18. Special heavy-duty sockets must be used on impact wrenches. If ordinary sockets are used on an impact wrench, they may break and cause serious personal injury.

Compressed-Air Equipment Safety

The shop air supply contains high-pressure air in the shop compressor and air lines. Serious injury or property damage may result from careless operation of compressed-air equipment.

Follow these steps to improve safety:

1. Never operate an air chisel unless the tool is securely connected to the chisel with the proper retaining device.
2. Never direct a blast of air from an air gun toward any part of your body. If air penetrates the skin and enters the bloodstream, it may cause very serious health problems and even death.
3. Safety glasses or a face shield should be worn for all shop tasks, including those tasks involving the use of compressed-air equipment.
4. Wear ear protection when using compressed-air equipment.
5. Always maintain air hoses and fittings in good condition. If an end suddenly blows off an air hose, the hose will whip around, causing possible personal injury.
6. Do not direct compressed air against the skin, because it may penetrate the skin, especially through small cuts or scratches, and enter the bloodstream, causing death or serious health complications. Use only OSHA-approved air gun nozzles.
7. Do not use an air gun to blow debris off clothing or hair.
8. Do not clean the workbench or floor with compressed air. This action may blow very small parts toward your skin or into your eye. Small parts blown by compressed air may also cause vehicle damage. For example, if the car in the next stall has the air cleaner removed, a small part may find its way into the carburetor or throttle body. When the engine is started, this part will likely be pulled into a cylinder by engine vacuum, and the part will penetrate through the top of a piston.
9. Never spin bearings with compressed air because the bearing will rotate at extremely high speed. This may damage the bearing or cause it to disintegrate, causing personal injury.
10. All pneumatic tools must be operated according to the tool manufacturer's recommended operating procedure.
11. Follow the equipment manufacturer's recommended maintenance schedule for all compressed-air equipment.

Cleaning Equipment Safety and Environmental Considerations

Cleaning Equipment Safety

All technicians are required to clean parts during their normal work routines. Face shields and protective gloves must be worn while operating cleaning equipment. In most states, environmental regulations require that the runoff from steam cleaning must be contained in the steam cleaning system. This runoff cannot be dumped into the sewer system. Because it is expensive to contain this runoff in the steam cleaning system, the popularity of steam cleaning has decreased. The solution in hot and cold cleaning tanks may be caustic, and contact between this solution and skin or eyes must be avoided. Parts cleaning often creates a slippery floor, and care must be taken when walking in the parts cleaning area. The floor in this area should be cleaned frequently. When the cleaning solution in hot or cold cleaning tanks is replaced, environmental regulations require that the old solution be handled as hazardous waste. Use caution when placing aluminum or aluminum alloy parts in a cleaning solution. Some cleaning solutions will damage these components. Always follow the cleaning equipment manufacturer's recommendations.

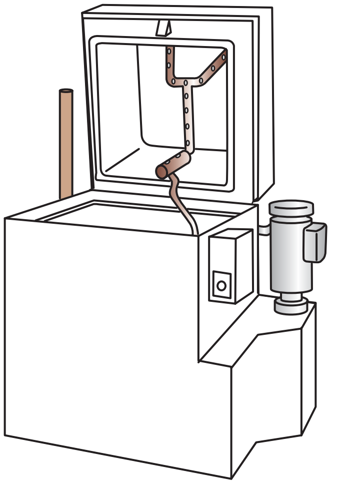


FIGURE 1-18 **Parts washer with electromechanical agitation.**

Parts Washers with Electromechanical Agitation

A **hot cleaning tank** uses a heated solution to clean metal parts.

Some parts washers provide electromechanical agitation of the parts to provide improved cleaning action (Figure 1-18). These parts washers may be heated with gas or electricity. Various water-based **hot cleaning tank** solutions are available, depending on the type of metals being cleaned. For example, Kleer-Flo Greasoff® No. 1 powdered detergent is available for cleaning iron and steel. Nonheated electromechanical parts washers are also available, and these washers use cold cleaning solutions such as Kleer-Flo Degreasol® formulas.

Many cleaning solutions, such as Kleer-Flo Degreasol® 99R, contain no ingredients listed as hazardous by the Environmental Protection Agency's Resource Conservation and Recovery Act (RCRA). This cleaning solution is a blend of sulfur-free hydrocarbons, wetting agents, and detergents. Degreasol® 99R does not contain aromatic or chlorinated solvents, and it conforms to California's Rule 66 for clean air. Always use the cleaning solution recommended by the equipment manufacturer.

Cold Parts Washer with Agitation Immersion Tank

A **cold parts washer** uses a nonheated solution to clean metal parts.

Some parts washers have an agitator immersion chamber under the shelves that provides thorough parts cleaning. Folding work shelves provide a large upper cleaning area with a constant flow of solution from the dispensing hose (Figure 1-19). This **cold parts washer** operates on Degreasol® 99R cleaning solution.

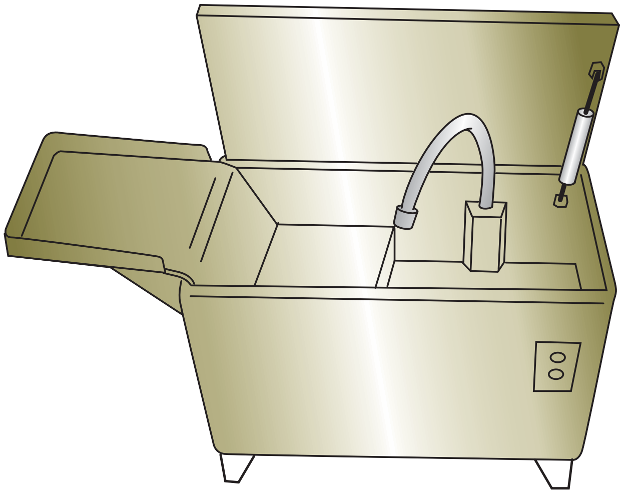


FIGURE 1-19 **Cold parts washer with agitated immersion tank.**

FIGURE 1-20 **Aqueous parts cleaning tank.**

Aqueous Parts Cleaning Tank

The **aqueous parts cleaning tank** uses a water-based, environmentally friendly cleaning solution, such as Greasoff® 2, rather than traditional solvents. The immersion tank is heated and agitated for effective parts cleaning (Figure 1-20). A sparger bar pumps a constant flow of cleaning solution across the surface to push floating oils away, and an integral skimmer removes these oils. This action prevents floating surface oils from redepositing on cleaned parts.

Handling Shop Wastes

The shop is responsible for hazardous waste until such waste is delivered to a hazardous waste site. Many shops contract a hazardous waste hauler to transport hazardous waste from the shop to government-approved recyclers or hazardous waste disposal sites. Always hire a properly licensed waste hauler, and have a written contract with them. Be sure you know how the waste hauler disposes of shop wastes. The hazardous waste hauler fills out the necessary forms related to waste disposal and communicates with state and federal agencies that are in charge of hazardous waste disposal regulations. Keep all shipping bills from your hazardous waste hauler to prove you have recycled or disposed of hazardous waste material.

Batteries

Batteries should be recycled by shipping them to a reclaimer or back to the battery distributor. When defective batteries are stored on-site, they should be kept in watertight, acid-resistant containers. Acid residue from batteries is hazardous because it is corrosive and may contain lead and other toxins. Inspect defective batteries for cracks and leaks. Cover spilled battery acid with baking soda or lime to neutralize it, then clean up and dispose of any other hazardous material.

Oil

Used oil is commonly hauled to an oil recycling facility. Place oil drip pans under a vehicle with oil leaks so oil does not drip onto the storage area. In some states it is legal to burn used oil in a commercial space heater. State and local authorities must be contacted regarding regulations and permits.

Oil Filters

Used oil filters should be allowed to drain into an appropriate drip pan for 24 hours. After the draining process, oil filters should be squashed and recycled.

Solvents

Parts cleaning equipment that uses hazardous cleaning chemicals should be replaced with cleaning equipment that uses water-based degreasers. If hazardous chemicals are used in cleaning equipment, these chemicals must be recycled or disposed of as hazardous waste. Evaporation from spent cleaning chemicals is a contributor to ozone depletion and smog formation. Spent cleaning chemicals should be placed in closed, labeled containers and stored in drip pans or in diked areas. The storage area for waste materials should be covered to prevent rain from washing contaminants from stored materials into the groundwater. This storage area may have to be fenced and locked if vandalism is a possibility.

Liquids

Engine coolant should be collected and recycled in an approved coolant recycling machine. Other liquids such as brake fluid and transmission fluid should be labeled and stored in the same area as solvents. Used brake fluid or transmission fluid should be recycled or disposed of as hazardous waste material.

The **Environmental Protection Agency (EPA)** is the federal agency responsible for air and water quality in the United States.

Shop Towels

When dirty shop towels are stored on-site, they should be placed in closed containers that are clearly marked "Contaminated shop towels only." Shop towels should be cleaned by a laundry service that has the capability to treat the wastewater generated by cleaning these towels.

Refrigerants

When servicing automotive air-conditioning systems, it is illegal to vent refrigerants to the atmosphere. Certified equipment must be used to recover and recycle the refrigerant and to recharge air-conditioning systems. This service work must be performed by an EPA-certified technician.

The EPA approves a Refrigerant Recovery and Recycling Review and Quiz supplied by the National Institute for Automotive Service Excellence (ASE). Upon successful completion of the ASE review and quiz, a technician is certified to service mobile A/C refrigerant systems. The ASE review and quiz meets Section 609 regulations in the Clean Air Act Amendments.

A material that is **reactive** reacts with some other chemicals and gives off gas(es) during the reaction.

Hazardous Waste Disposal

Hazardous waste materials in automotive shops are chemicals or components that the shop no longer needs. These materials pose a danger to the environment and to people if they are disposed of in ordinary trash cans or sewers. However, no material is considered hazardous waste until the shop has finished using it and is ready to dispose of it. The **Environmental Protection Agency (EPA)** publishes a list of hazardous materials, which is included in the Code of Federal Regulations. Waste is considered hazardous if it is included on the EPA list of hazardous materials, or if it has one or more of these characteristics:

A material that is **corrosive** causes another material to be gradually worn away by chemical action.

1. **Reactive**. Any material that reacts violently with water or other chemicals is considered hazardous. If a material releases cyanide gas, hydrogen sulphide gas, or similar gases when exposed to low-pH acid solutions, it is hazardous.
2. **Corrosive**. If a material burns the skin or dissolves metals and other materials, it is considered hazardous.
3. **Toxic**. Materials are hazardous if they leach one or more of eight heavy metals in concentrations greater than 100 times the primary drinking water standard.
4. **Ignitable**. A liquid is hazardous if it has a flashpoint below 140°F (60°C). A solid is hazardous if it ignites spontaneously.

A **toxic** substance is poisonous to animal or human life.

A substance that is **ignitable** can be ignited spontaneously or by another source of heat or flame.

Federal and state laws control the disposal of hazardous waste materials. Every shop employee must be familiar with these laws. Hazardous waste disposal laws include the **Resource Conservation and Recovery Act (RCRA)**. This law states that hazardous material users are

FIGURE 1-21 **Hazardous waste hauler.**

responsible for hazardous materials from the time they become waste until the proper waste disposal is completed. Many automotive shops hire an independent hazardous waste hauler to dispose of hazardous waste material (Figure 1-21). The shop owner or manager should have a written contract with the hazardous waste hauler. Rather than hauling hazardous waste material to an approved hazardous waste disposal site, a shop may choose to recycle the material in the shop; therefore, hazardous waste material must be properly and safely stored. The user is responsible for the transportation of this material until it arrives at an approved hazardous waste disposal site and is processed according to the law.

The RCRA controls these types of automotive waste:

1. Paint and body repair products waste
2. Solvents for parts and equipment cleaning
3. Batteries and battery acid
4. Mild acids used for metal cleaning and preparation
5. Waste oil, engine coolants, and antifreeze
6. Air-conditioning refrigerants
7. Engine oil filters

Never, under any circumstances, use these methods to dispose of hazardous waste material:

1. Pour hazardous wastes on weeds to kill them.
2. Pour hazardous wastes on gravel streets to prevent dust.
3. Throw hazardous wastes in a dumpster.
4. Dispose of hazardous wastes anywhere but an approved disposal site.
5. Pour hazardous wastes down sewers, toilets, sinks, or floor drains.

The Right-to-Know Laws state that employees have a right to know when the materials they use at work are hazardous. The Right-to-Know Laws started with the **Hazard Communication Standard** published by the Occupational Safety and Health Administration (OSHA) in 1983. This document was originally intended for chemical companies and manufacturers that required employees to handle hazardous materials in their work situation. Currently, most states have established their own Right-to-Know Laws. Meanwhile, federal courts have decided to apply these laws to all companies, including automotive service shops. Under the Right-to-Know Laws, the employer has three responsibilities regarding the handling of hazardous materials by its employees.

Material safety data sheets (MSDS) provide all the necessary data about hazardous materials.

First, all employees must be trained about the types of hazardous materials they will encounter in the workplace. Employees must be informed about their rights under legislation regarding the handling of hazardous materials. All hazardous materials must be properly labeled, and information about each hazardous material must be posted on **material safety data sheets (MSDS)**, which are available from the manufacturer (Figure 1-22). In Canada, MSDSs may be called **workplace hazardous materials information systems (WHMIS)**.

MATERIAL SAFETY DATA SHEET

PRODUCT NAME: KLEAN-A-KARB (aerosol) #- HPMS 102068
PRODUCT: 5078, 5931, 6047T
(page 1 of 2)

1. Ingredients	CAS #	ACGIH TLV	OSHA PEL	OTHER LIMITS	%
Acetone	67-64-1	750 ppm	750 ppm		2–5
Xylene	1330-20-7	100 ppm	100 ppm		68–75
2-Butoxy Ethanol	111-76-2	25 ppm	25 ppm	(skin)	3–5
Methanol	67-56-1	200 ppm	200 ppm		3–5
Detergent	-	NA	NA		0–1
Propane	74-98-6	NA	1000 ppm		10–20
Isobutane	75-28-5	NA	NA	1000 ppm	10–20

2. PHYSICAL DATA : (without propellent)
Specific Gravity : 0.865 — Vapor Pressure : ND
% Volatile : >99
Boiling Point : 176°F Initial — Evaporation Rate : Moderately Fast
Freezing Point : ND — Vapor Density : ND
Solubility: Partially soluable in water — pH :NA
Appearance and Odor: A clear colorless liquid, aromatic odor

3. FIRE AND EXPLOSION DATA
Flashpoint : –40°F — Method : TCC
Flammable Limits propellent — LEL: 1.8 UEL: 9.5
Extinguishing Media: CO2, dry chemical, foam
Unusual Hazards : Aerosol cans may explode when heated above 120°F.

4. REACTIVITY AND STABILITY
Stability : Stable
Hazardous decomposition products: CO2, carbon monoxide (thermal)

5. PROTECTION INFORMATION
Ventilation : Use mechanical means to ensure vapor concentration is below TLV.
Respiratory: Use self-contained breathing apparatus above TLV.

Gloves : Solvent resistant — Eye and Face: Safety Glasses
Other Protective Equipment: Not normally required for aerosol product usage

FIGURE 1-22 **Material safety data sheets (MSDS) inform employees about hazardous materials.**

The employer has a responsibility to place MSDSs where they are easily accessible by all employees. The MSDSs provide extensive information about hazardous materials such as:

1. Chemical name.
2. Physical characteristics.
3. Protective equipment required for handling.
4. Explosion and fire hazards.
5. Other incompatible materials.
6. Health hazards such as signs and symptoms of exposure, medical conditions aggravated by exposure, and emergency and first-aid procedures.
7. Safe handling precautions.
8. Spill and leak procedures.

Second, the employer has a responsibility to make sure that all hazardous materials are properly labeled. The label information must include health, fire, and reactivity hazards posed by the material and the protective equipment necessary to handle the material. The manufacturer must supply all warning and precautionary information about hazardous materials, and this information must be read and understood by the employee before handling the material.

Third, employers are responsible for maintaining permanent files regarding hazardous materials. These files must include information on hazardous materials in the shop, proof of employee training programs, and information about accidents such as spills or leaks of hazardous materials. The employer's files must also include proof that employees' requests for hazardous material information such as MSDSs have been met. A general right-to-know compliance procedure manual must be maintained by the employer.

CASE STUDY

A technician raised a Grand Marquis on a lift to perform an oil and filter change and a chassis lubrication. This lift was a twin-post-type with separate front and rear lift posts. On this type of lift, the rear wheels must be positioned in depressions in the floor to position the rear axle above the rear lift arm. Then the front lift post and arms must be moved forward or rearward to position the front lift arms under the front suspension. The front lift arms must also be moved inward or outward so they are lifting on the vehicle manufacturer's specified lifting points.

The technician carefully positioned the front lift post and arms properly, but forgot to check the position of the rear tires in the floor depressions. The car was raised on the lift, and the technician proceeded with the service work. Suddenly there was a loud thump, and the rear of the car bounced up and down! The rear lift arms were positioned against the floor of the trunk rather than on the rear axle, and the lift arms punched through the floor of the trunk, narrowly missing the fuel tank. The technician was extremely fortunate the car did not fall off the lift, resulting in more severe damage. If the rear lift arms had punctured the fuel tank, a disastrous fire could have occurred! Luckily, these things did not happen.

The technician learned a very important lesson about lift operation. Always follow all the recommended procedures in the lift operator's manual! The trunk floor was repaired at no cost to the customer, and fortunately, the shop and the vehicle escaped without major damage.

Terms to Know

Air bag system
Approved gasoline storage cans
Aqueous parts cleaning tank
Brake parts washer
Cold parts washer
Corrosive
Environmental Protection Agency (EPA)
Fluorescent trouble lights
Hazard Communication Standard
Hot cleaning tank
Ignitable
Incandescent bulb-type trouble lights
Material safety data sheets (MSDSs)
Multipurpose dry chemical fire extinguisher
Occupational Safety and Health Act (OSHA)
Reactive
Resource Conservation and Recovery Act (RCRA)
Right-to-Know Laws
Toxic
Workplace hazardous materials information systems (WHMIS)

Summary

- The U.S. Occupational Safety and Health Act (OSHA) of 1970 ensures safe and healthful working conditions and authorizes enforcement of safety standards.
- Many hazardous materials and conditions can exist in an automotive shop, including flammable liquids and materials, corrosive acid solutions, loose sewer covers, caustic liquids, high-pressure air, frayed electrical cords, hazardous waste materials, carbon monoxide, improper clothing, harmful vapors, high noise levels, and spills on shop floors.
- Material safety data sheets (MSDSs) provide information regarding hazardous materials, labeling, and handling.
- The danger regarding hazardous conditions and materials may be avoided by eliminating shop hazards and applying the necessary shop rules and safety precautions.
- The automotive shop owner/management must supply the necessary shop safety equipment, and all shop personnel must be familiar with the location and operation of this equipment. Shop safety equipment includes gasoline safety cans, steel storage cabinets, combustible material containers, fire extinguishers, eyewash fountains, safety glasses and face shields, first-aid kits, and hazardous waste disposal containers.
- General shop safety includes following all safety rules and precautions to ensure a safe working environment and reduce on-the-job injuries.
- Maintaining adequate personal safety requires technicians to wear protective clothing such as proper footwear with steel toe caps, and safety glasses or a face shield. Technicians must avoid wearing loose fitting clothing that may become entangled in rotating equipment or components.
- To provide adequate personal safety, technicians must avoid wearing watches, jewelry, or rings.
- Shop safety requires a properly ventilated shop with an adequate exhaust removal system to avoid carbon monoxide gas in the shop.
- Shop safety equipment such as first-aid kits, eyewash fountains, and fire extinguishers must be clearly marked and easily accessible.
- Electrical cords must have a ground connection, and frayed electrical cords must be repaired or replaced immediately.
- Gasoline must be stored in clearly marked, approved gasoline containers.
- Fire safety in the shop includes storing combustible materials in approved, covered safety containers, avoiding sparks and flames near combustible materials, and quickly cleaning up gasoline, oil, or grease spills.
- To maintain shop safety, technicians must be familiar with the location and operation of fire extinguishers.
- Technicians must follow proper driving rules when driving vehicles in the shop.
- Proper lifting procedures must be followed to avoid personal injury when lifting heavy objects.
- Safe operating procedures must be followed when using hand tools and operating shop equipment such as lifts, hydraulic jacks, power tools, compressed air equipment, and cleaning equipment.

ASE-Style Review Questions

1. Breathing carbon monoxide may cause:
   A. Arthritis C. Impaired vision
   B. Cancer D. Headaches
2. While discussing shop rules:
   Technician A says breathing asbestos dust may cause heart defects.
   Technician B says oily rags should be stored in uncovered trash containers.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
3. All these shop rules are correct EXCEPT:
   A. USC tools may be substituted for metric tools.
   B. Foot injuries may be caused by loose sewer covers.
   C. Hands should be kept away from electric-drive cooling fans.
   D. Power tools should not be left running and unattended.
4. While discussing personal safety:
   Technician A says rings and jewelry may be worn in the automotive shop.
   Technician B says some electric-drive cooling fans may start turning at any time.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
5. While lifting heavy objects in the automotive shop:
   A. Bend your back to pick up the heavy object.
   B. Place your feet as far as possible from the object.
   C. Bend forward to place the object on the workbench.
   D. Straighten your legs to lift an object off the floor.
6. While discussing power tool safety:
   Technician A says an electric power tool cord does not require a ground.
   Technician B says frayed electric cords should be replaced.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
7. While operating hydraulic equipment safely in the automotive shop remember that:
   A. Safety stands have a maximum weight capacity.
   B. The driver's door should be open when raising avehicle on a lift.
   C. A lift does not require a safety mechanism to prevent lift failure.
   D. Four-wheel drive vehicles should be lifted on a frame contact lift.
8. While discussing shop hazards:
   Technician A says high-pressure air from an air gun may penetrate the skin.
   Technician B says air in the bloodstream may be fatal.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
9. While discussing hazardous material disposal:
   Technician A says certain types of hazardous waste material can be poured down a floor drain.
   Technician B says a shop is responsible for hazardous waste materials from the time they become waste until the proper waste disposal is completed.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
10. When working in an automotive shop, hazardous conditions must be avoided by:
    A. Storing oily rags in open containers.
    B. Storing flammable liquids such as paint in metal cupboards.
    C. Leaving sewer covers loose for quick access.
    D. Cleaning brake parts with an air gun.

Name ________________________________ Date ____________________

Demonstrate Proper Lifting Procedures

Upon completion of this job sheet, you should be able to follow the proper procedure when lifting heavy objects.

Tools and Materials

A heavy object with a weight that is within the weight-lifting capability of the technician.

Procedure

Task Completed

Have various members of the class demonstrate proper weight-lifting procedures by lifting an object off the shop floor and placing it on the workbench. Other class members are to observe and record any improper weight-lifting procedures.

1. If the object is to be carried, be sure your path is free from loose parts or tools. ☐
2. Position your feet close to the object, and position your back reasonably straight for proper balance. ☐
3. Your back and elbows should be kept as straight as possible. Continue to bend your knees until your hands reach the best lifting location on the object to be lifted. ☐
4. Be certain the container is in good condition. If a container falls apart during the lifting operation, parts may drop out of the container, resulting in foot injury or part damage. ☐
5. Maintain a firm grip on the object; do not attempt to change your grip while lifting is in progress. ☐
6. Straighten your legs to lift the object, keeping the object close to your body. Use leg muscles rather than back muscles. ☐
7. If you have to change direction of travel, turn your whole body. Do not twist. ☐
8. Do not bend forward to place an object on a workbench or table. Position the object on the front surface of the workbench and slide it back, watching your fingers under the object to avoid pinching them. ☐
9. If the object must be placed on the floor or a low surface, bend your legs to lower the object. Do not bend your back forward because this movement strains back muscles. ☐
10. When a heavy object must be placed on the floor, put suitable blocks under the object to prevent jamming your fingers under the object. ☐

11. List any improper weight-lifting procedures observed during the weight-lifting demonstrations.

1. ______________________________
2. ______________________________
3. ______________________________
4. ______________________________
5. ______________________________
6. ______________________________

Instructor's Response ______________________________

____

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Name ______________________________ **Date** ____________________

Locate and Inspect Shop Safety Equipment

Upon completion of this job sheet, you should be familiar with the location of shop safety equipment and know if this equipment is serviced properly.

Procedure

Task Completed

1. Fire extinguishers: Are the fire extinguishers tagged to indicate they have been checked or serviced recently? ☐ Yes ☐ No

   Draw a basic diagram of the shop layout in the space below, and mark the locations of the fire extinguishers and fire exits.

2. Eyewash fountain or shower: Is the eyewash fountain or shower operating properly?

   ☐ Yes ☐ No

   Mark the location of the eyewash fountain or shower on the shop layout diagram instep 1.

3. First-aid kits: Are the first-aid kits properly stocked with supplies?

   ☐ Yes ☐ No

   Mark the location of the first-aid kits on the shop layout diagram in step 1.

4. Electrical shut-off box: Mark the location of the shop electrical shut-off box on the shop layout diagram in step 1. ☐

5. Are the trash containers equipped with proper covers?

   ☐ Yes ☐ No

   Mark the location of the trash containers on the shop layout diagram in step 1.

6. Metal storage cabinet: Mark the location of metal storage cabinet(s) for combustible materials on the shop layout diagram in step 1. ☐

Instructor's Response ____

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Name ______________________________ Date ____________________

Shop Housekeeping Inspection

Upon completion of this job sheet, you should be able to apply shop housekeeping rules in your shop.

Procedure

Task Completed

When students from another class of Automotive Technology are working in the shop, evaluate their shop housekeeping procedures using the 16 shop housekeeping procedures. List all the improper shop housekeeping procedures that you observed in the space provided at the end of the job sheet.

1. Keep aisles and walkways clear of tools, equipment, and other items. ☐
2. Be sure all sewer covers are securely in place. ☐
3. Keep floor surfaces free of oil, grease, water, and loose material.
4. Proper trash containers must be conveniently located, and these containers should be emptied regularly. ☐
5. Access to fire extinguishers must be unobstructed at all times; fire extinguishers should be checked for proper charge at regular intervals. ☐
6. Tools must be kept clean and in good condition. ☐
7. When not in use, tools must be stored in their proper location. ☐
8. Oily rags and other combustibles must be placed in proper, covered metal containers. ☐
9. Rotating components on equipment and machinery must have guards. All shop equipment should have regular service and adjustment schedules. ☐
10. Benches and seats must be kept clean. ☐
11. Keep parts and materials in their proper location. ☐
12. When not in use, creepers must not be left on the shop floor. Creepers should be stored in a specific location. ☐
13. The shop should be well-lit, and all lights should be in working order. ☐
14. Frayed electrical cords on lights or equipment must be replaced. ☐
15. Walls and windows should be cleaned regularly. ☐

Task Completed

☐ **16.** Stairs must be clean, well-lit, and free of loose material.

Observed improper shop housekeeping procedures:

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

Instructor's Response ______________________________

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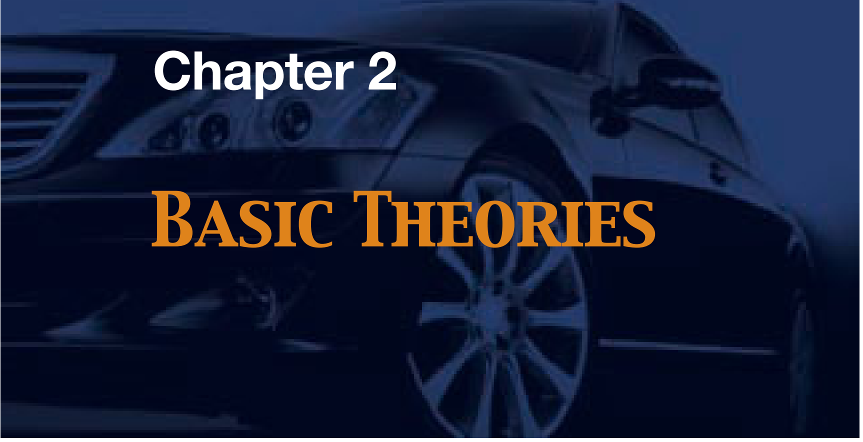

Chapter 2

Basic Theories

Upon completion and review of this chapter, you should be able to understand and describe:

- Newton's Laws of Motion.
- Work and force.
- Power.
- The most common types of energy and energy conversions.
- Inertia and momentum.
- Friction.
- Mass, weight, and volume.
- Static unbalance.
- Dynamic unbalance.
- The compressibility of gases and the noncompressibility of liquids.
- Atmospheric pressure and vacuum.
- Venturi operation.

A Bit of History

The automotive industry in the United States is a very large, dynamic industry. Total production of passenger cars, trucks, buses, and commercial vehicles has increased from 4,192 in 1900 to 12,770,714 in 2000. Since 1920, the lowest vehicle production was 725,215 in 1945.

Introduction

An understanding of the basics is essential before you attempt a study of complex systems and components. Basic theories such as static balance, dynamic balance, and compressibility must be understood prior to a study of the components and systems in this book. If you have studied basic theories previously, the information in this chapter may be used as a review. A thorough study of this chapter will provide all the necessary background information you need before you study the suspension and steering systems in this book.

Newton's Laws of Motion

First Law

A body in motion remains in motion, and a body at rest remains at rest, unless some outside force acts on it. When a car is parked on a level street, it remains stationary unless it is driven or pushed. If the gas pedal is depressed with the engine running and the transmission in drive, the engine delivers power to the drive wheels and this force moves the car.

Second Law

A body's acceleration is directly proportional to the force applied to it, and the body moves in a straight line away from the force. For example, if the engine power supplied to the drive wheels increases, the vehicle accelerates faster.

Third Law

For every action, there is an equal and opposite reaction. A practical application of this law occurs when the wheel on a vehicle strikes a bump in the road surface. This action drives the

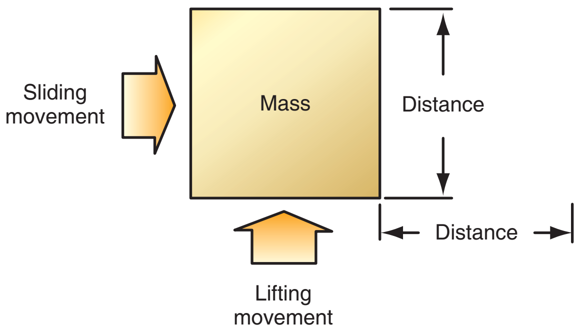

FIGURE 2-1 **Work is accomplished when a mass is lifted or slid on a surface.**

wheel and suspension upward with a certain force, and a specific amount of energy is stored in the spring. After this action occurs, the spring forces the wheel and suspension downward with a force equal to the initial upward force.

Work and Force

When a **force** moves a certain mass a specific distance, **work** is produced. When work is accomplished, the mass may be lifted or slid on a surface (Figure 2-1). Since force is measured in pounds and distance is measured in feet, the measurement for work is foot-pounds (ft-lb). In the metric system, work is measured in Newton meters (Nm). If a force moves a 3,000-pound vehicle for 50 feet, 150,000 foot-pounds of work are produced. Mechanical force acts on an object to start, stop, or change the direction of the object. It is possible to apply force to an object and not move the object. For example, you may push with all your strength on a car stuck in a ditch and not move the car. Under this condition, no work is done. Work is only accomplished when an object is started, stopped, or redirected by mechanical force.

Force is defined as energy applied to an object.

Work is defined as the result of applying a force.

Energy

When **energy** is released to do work, it is called kinetic energy. This type of energy may also be referred to as energy in motion. Stored energy may be called potential energy. Energy is available in one of six forms:

Energy may be defined as the ability to do work.

1. *Chemical energy* is contained in the molecules of different atoms. In the automobile, chemical energy is contained in the molecules of gasoline and also in the molecules of electrolyte in the battery.
2. *Electrical energy* is required to move electrons through an electric circuit. In the automobile, the battery is capable of producing electrical energy to start the vehicle, and the alternator produces electrical energy to power the electrical accessories and recharge the battery.
3. *Mechanical energy* is the ability to move objects. In the automobile, the battery supplies electrical energy to the starting motor, and this motor converts the electrical energy to mechanical energy to crank the engine. Because this energy is in motion, it may be called kinetic energy.
4. *Thermal energy* is energy produced by heat. When gasoline burns, thermal energy is released.
5. *Radiant energy* is light energy. In the automobile, radiant energy is produced by the lights.
6. *Nuclear energy* is the energy within atoms when they are split apart or combined. Nuclear power plants generate electricity with this principle. This type of energy is not used in the automobile.

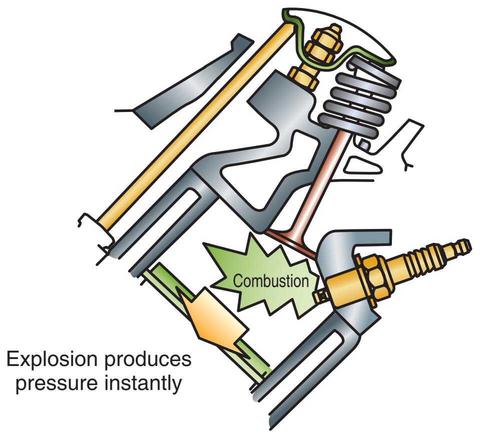

FIGURE 2-2 **Thermal energy in the fuel is converted to mechanical energy in the engine cylinders. The piston, crankshaft, and drive train deliver this mechanical energy to the drive wheels.**

Energy Conversion

Energy conversion occurs when one form of energy is changed to another form. Since energy is not always in the desired form, it must be converted to a form we can use. Some of the most common automotive energy conversions are discussed in the following sections.

Chemical to Thermal Energy Conversion

Chemical energy in gasoline or diesel fuel is converted to thermal energy when the fuel burns in the engine cylinders.

Thermal to Mechanical Energy Conversion

Mechanical energy is required to rotate the drive wheels and move the vehicle. The piston and crankshaft in the engine and the drive train are designed to convert the thermal energy produced by the burning fuel into mechanical energy (Figure 2-2).

Electrical to Mechanical Energy Conversion

The windshield wiper motor converts electrical energy from the battery or alternator to mechanical energy to drive the windshield wipers.

Mechanical to Electrical Energy Conversion

The alternator is driven by mechanical energy from the engine. The alternator converts this energy to electrical energy, which powers the electrical accessories on the vehicle and recharges the battery.

Inertia is defined as the tendency of an object at rest to remain at rest or the tendency of an object in motion to stay in motion.

Inertia

The **inertia** of an object at rest is called static inertia, whereas dynamic inertia refers to the inertia of an object in motion. Inertia exists in liquids, solids, and gases. When you push and move a parked vehicle, you overcome the static inertia of the vehicle. If you catch a ball in motion, you overcome the dynamic inertia of the ball.

When a force overcomes static inertia and moves an object, the object gains **momentum**.

Momentum

Momentum is the product of an object's weight times its speed. Momentum is a type of mechanical energy. An object loses momentum if another force overcomes the dynamic inertia of the moving object.

Friction

Friction may occur in solids, liquids, and gases. When a car is driven down the road, friction occurs between the air and the car's surface. This friction opposes the momentum, or mechanical energy, of the moving vehicle. Since friction creates heat, some of the mechanical energy from the vehicle's momentum is changed to heat energy in the air and body components. The mechanical energy from the engine must overcome the vehicle's inertia and the friction of the air striking the vehicle. Body design has a very dramatic effect on the amount of friction developed by the air striking the vehicle. The total resistance to motion caused by friction between a moving vehicle and the air is referred to as coefficient of drag (Cd). The study of Cd is not only very complicated but also very important. At 45 miles per hour (72 kilometers per hour), half of the engine's mechanical energy is used to overcome air friction, or resistance. Therefore, reducing a vehicle's Cd can be a very effective method of improving fuel economy and reducing CO_2 emissions.

Friction may be defined as the resistance to motion when the surface of one object is moved over the surface of another object.

Coefficient of drag (Cd) may also be called aerodynamic drag.

Mass, Weight, and Volume

A lawn mower is much easier to push than a 2,500-pound vehicle because the lawn mower has very little inertia compared to the vehicle. A space ship might weigh 100 tons here on earth where it is affected by the earth's gravitational pull. In outer space beyond the earth's gravity and atmosphere, the space ship is almost weightless. Here on earth, **mass** and **weight** are measured in pounds and ounces in the English system. In the metric system, mass and weight are measured in grams or kilograms.

Volume is a measurement of size, and it is related to mass and weight. For example, a pound of gold and a pound of feathers both have the same weight, but the pound of feathers occupies a much larger volume. In the English system, volume is measured in cubic inches, cubic feet, cubic yards, or gallons. The measurement for volume in the metric system is cubic centimeters or liters.

Mass is the measurement of an object's inertia.

Weight is the measurement of the earth's gravitational pull on the object.

Volume is the length, width, and height of a space occupied by an object.

Torque

When you pull a wrench to tighten a bolt, you supply **torque** to the bolt. If you pull on a wrench to check the torque on a bolt, and the bolt torque is sufficient, torque is applied to the bolt, but no movement occurs. This torque, or twisting force, is calculated by multiplying the force and the radius. For example, if you supply a 10 lb force on the end of a 2-ft wrench to tighten a bolt, the torque is $10 \times 2 = 20$ ft-lb (Figure 2-3). If the bolt turns during torque application, work is done. When a bolt does not rotate during torque application, no work is accomplished.

Torque is a force that does work with a twisting or turning force. However, movement does not have to occur.

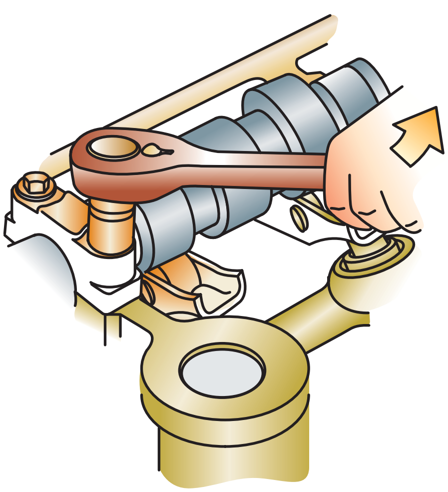

FIGURE 2-3 **Force applied to a wrench produces torque. If the bolt turns, work is accomplished.**

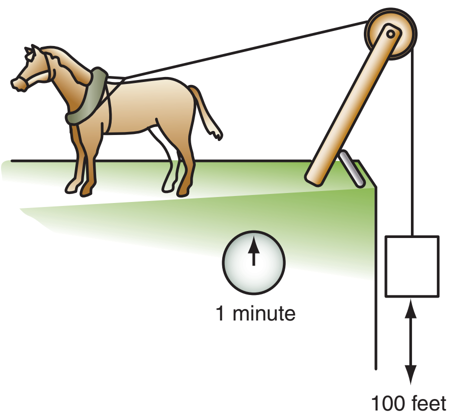

FIGURE 2-4 **One horsepower is produced when 330 lb are moved 100 ft in 1 minute.**

A BIT OF HISTORY

James Watt, a Scotsman, is credited with being the first person to calculate power. He measured the amount of work that a horse could do in a specific time.

Horsepower is a measurement for the rate, or speed, at which work is done.

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Chapter 2, page 45

Power

James Watt calculated that a horse could move 330 pounds for 100 feet in one minute (Figure 2-4). If you multiply 330 pounds by 100 feet, the answer is 33,000 foot-pounds of work. Watt determined that one horse could do 33,000 foot-pounds of work in one minute. Thus, one **horsepower** is equal to 33,000 foot-pounds per minute, or 550 foot-pounds per second. Two horsepower could do this same amount of work in one-half minute, or four horsepower could complete this work in one-quarter minute. If you push a 3,000-pound (1,360-kilogram) car for 11 feet (3.3 meters) in one-quarter minute, you produce four horsepower. From this brief discussion about horsepower, we can understand that as power increases, speed also increases, or the time to do work decreases.

Principles Involving Tires and Wheels in Motion

If you roll a cone-shaped piece of metal on a smooth surface, the cone does not move straight ahead. Instead, the cone moves toward the direction of the tilt on the cone. When you are riding a bicycle and want to make a left turn, if you tilt the bicycle to the left, it is much easier to complete the turn. The reason for this action is that a tilted, rolling wheel tends to move in the direction of the tilt. Similarly, if a tire and wheel on a vehicle are tilted, the tire and wheel tend to move in the direction of the tilt (Figure 2-5). This principle is used in front wheel alignment.

The casters on a piece of furniture are angled so the center of the caster wheel is some distance from the pivot center (Figure 2-6). When the furniture is moved, the casters turn

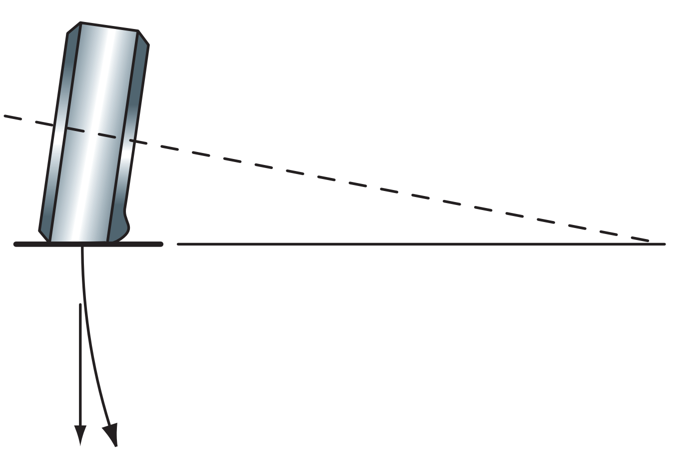

FIGURE 2-5 **A tilted, rolling wheel tends to move in the direction of the tilt.**

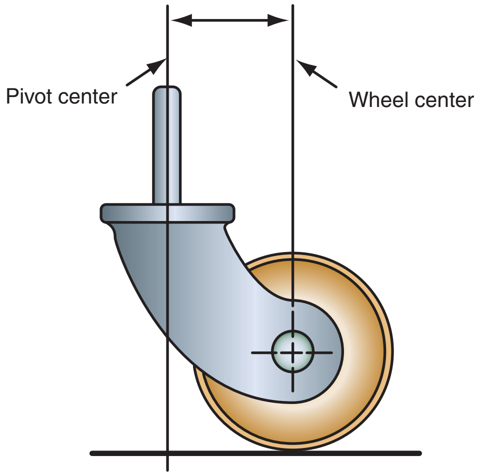

FIGURE 2-6 **Distance between the wheel center and the pivot center on a caster.**

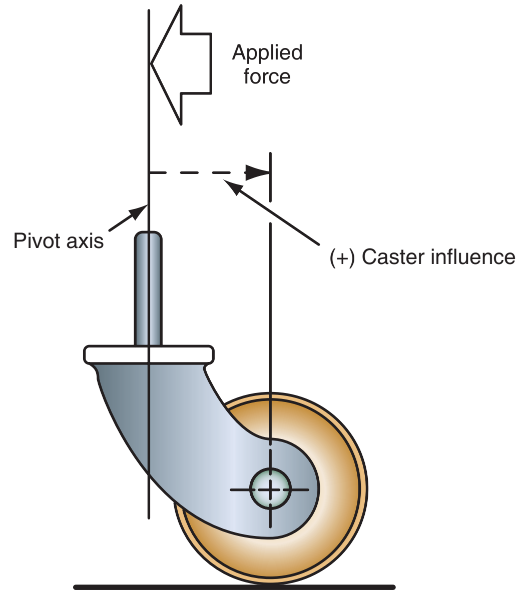

FIGURE 2-7 **Caster aligned with the pushing force provides straight-ahead movement when furniture is pushed.**

on their pivots to bring the caster wheels into line with the pushing force on the furniture (Figure 2-7). This caster action causes the furniture to move easily in a straight line.

Rolling tires and wheels that are tilted always move in the direction of the tilt.

The weight of a bicycle rider is projected through the bicycle front fork to the road surface, and the tire pivots on the vertical centerline of the wheel when the handlebars are turned. Notice the centerline of the front fork is tilted rearward in relation to the vertical centerline of the wheel (Figure 2-8). Since the tire pivot point is behind the front fork centerline where the weight is projected against the road surface, the front wheel tends to return to the straight-ahead position after a turn. The wheel also tends to remain in the straight-ahead position as the bicycle is driven. This principle is applied in automotive front wheel alignment.

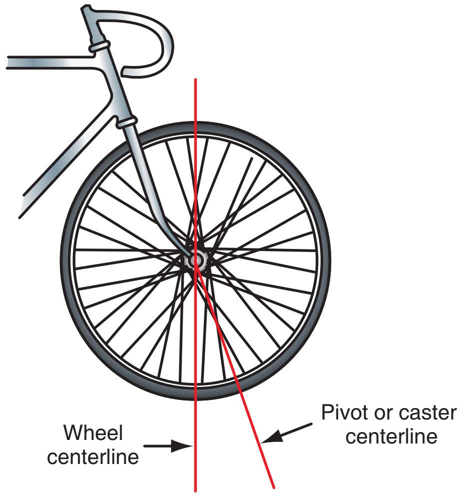

FIGURE 2-8 **If a wheel centerline and pivot point are behind the front fork centerline pivot point, the wheel tends to return to the straight-ahead position after a turn. The wheel also tends to remain in the straight-ahead position as the bicycle is driven.**

Static balance refers to the equal distribution of weight around the center of a tire-and-wheel assembly viewed from the side.

Dynamic balance refers to the equal distribution of weight on each side of a tire and wheel centerline viewed from the front or rear.

Principles Involving the Balance of Wheels in Motion

When the weight of a tire-and-wheel assembly is distributed equally around the center of wheel rotation viewed from the side, the wheel and tire have proper **static balance.** Under this condition, the tire-and-wheel assembly has no tendency to rotate by itself, regardless of the wheel position. If the weight is not distributed equally around the center of wheel rotation, the wheel and tire are statically unbalanced (Figure 2-9). As the wheel and tire rotate, centrifugal force acts on this static unbalance and causes the wheel to "tramp" or "hop." This wheel and tire action can often be seen while looking at tires on vehicles that may pass you on a highway.

When a ball is rotated on the end of a string, the ball and string form an angle with the axis of rotation. If the rotational speed is increased, the ball and string form a 90° angle with the axis of rotation (Figure 2-10). Any weight will always tend to rotate at a 90° angle to the axis of rotation.

If two balls are positioned on a metal bar so their weight is equally distributed on the centerline of the rotational axis of rotation, the path of rotation remains at a 90° angle to the centerline of the axis when the bar is rotated. Under this condition, the metal bar and the balls are in **dynamic balance** (Figure 2-11).

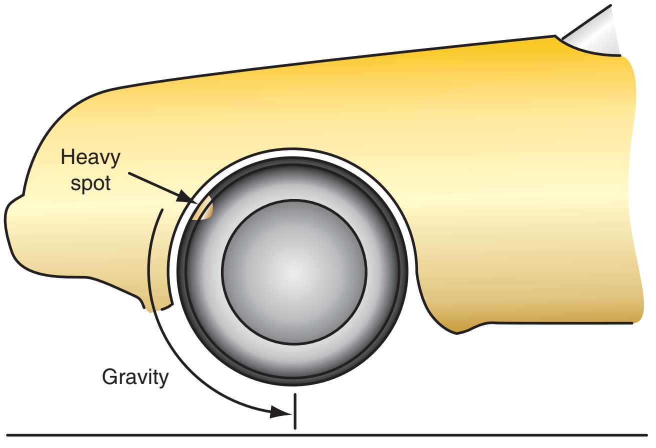

FIGURE 2-9 **Static wheel unbalance caused by unequal weight distribution around the center of the wheel rotation.**

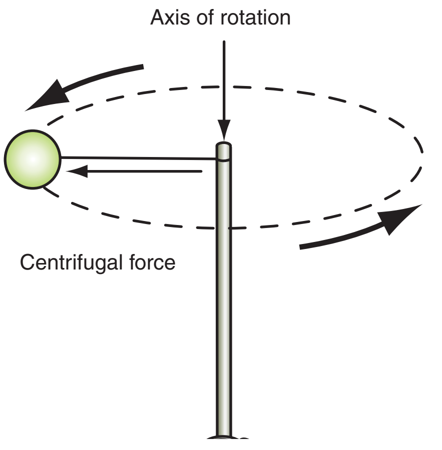

FIGURE 2-10 **A weight tends to rotate at a 90° angle in relation to the axis of rotation.**

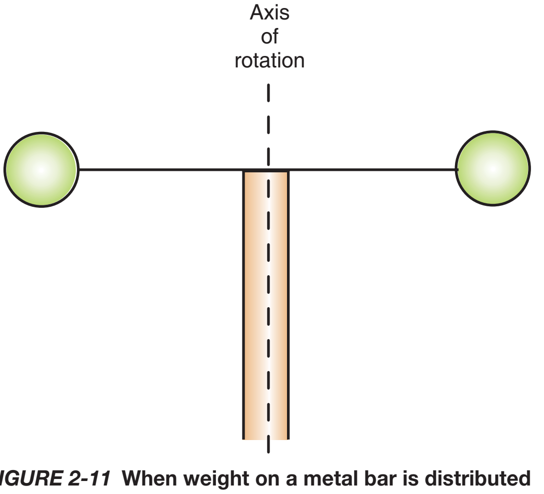

FIGURE 2-11 **When weight on a metal bar is distributed equally on the centerline of the axis of rotation, the bar and balls remain in dynamic balance during rotation.**

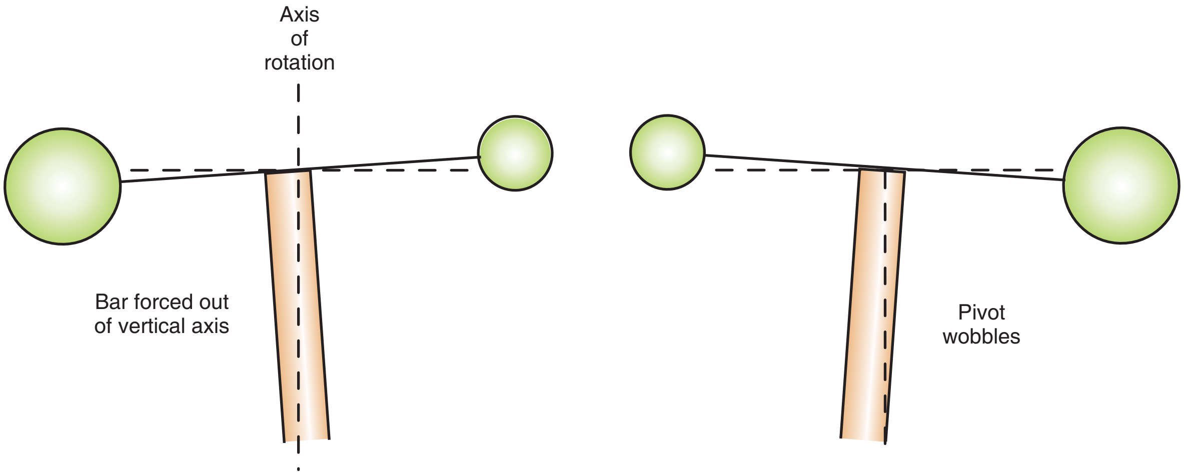

FIGURE 2-12 **When weight is not equally distributed in relation to the centerline of rotational axis, dynamic unbalance causes a wobbling action during rotation.**

If weights are placed on a metal bar so their weights are not equally distributed in relation to the centerline of the rotational axis of rotation, the weights still tend to rotate at a 90° angle in relation to the rotational axis. This action forces the pivot out of its vertical axis (Figure 2-12). When the bar is rotated 180°, the bar is forced out of its vertical axis in the opposite direction. If this condition is present, the bar has a wobbling action as it rotates. Under this condition, the bar is said to have dynamic unbalance, but static balance is maintained.

Similarly, when the weight on a tire and wheel is not distributed equally on both sides of the tire centerline viewed from the front, the tire and wheel are dynamically unbalanced. This condition produces a wobbling action as the tire and wheel rotate. The weight must be distributed equally in relation to the tire centerline to provide proper dynamic balance (Figure 2-13). These principles are used in automotive wheel balancing.

AUTHOR'S NOTE: Improper static or dynamic wheel balance causes excessive tire tread wear, increased wear on suspension components, and driver fatigue.

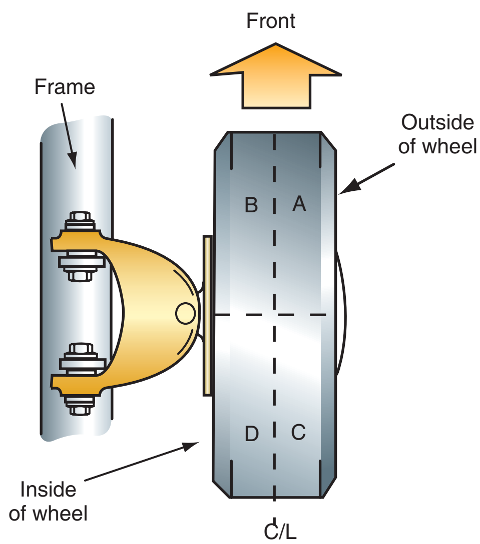

FIGURE 2-13 **Weight must be distributed equally in relation to the tire-and-wheel centerline.**

Molecular energy may be defined as the kinetic energy available in atoms and molecules because of the constant electron movement within the atoms and molecules.

Pressure may be defined as a force exerted on a given surface area.

Pressure and temperature are directly related. If you increase one, you also increase the other.

Pressure and volume are inversely proportional. If volume is decreased, pressure is increased.

Principles Involving Liquids and Gases

Molecular Energy

Remember that kinetic energy refers to energy in motion. Since electrons are constantly in motion around the nucleus in atoms or molecules, kinetic energy is present in all matter. Kinetic energy in atoms and molecules increases as the temperature increases. A decrease in temperature reduces the kinetic energy. Molecules in solids move slowly compared to those in liquids or gases. Gas molecules move quickly compared to liquid molecules. Since gas molecules are in constant motion, they spread out to fill all the space available. At higher temperatures, gas molecules spread out more, whereas at lower temperatures, gas molecules move closer together.

Temperature

Temperature affects all liquids, solids, and gases. The volume of any matter increases as the temperature increases. Conversely, the volume decreases in relation to a reduction in temperature. When the gases in an engine cylinder are burned, the sudden temperature increase causes rapid gas expansion, which pushes the piston downward and causes engine rotation (Figure 2-14).

Pressure and Compressibility

Since liquids and gases are both substances that flow, they may be classified as fluids. If a nail punctures an automotive tire, the air escapes until the pressure in the tire is equal to atmospheric pressure outside the tire. When the tire is repaired and inflated, air pressure is forced into the tire. If the tire is inflated to 32 pounds per square inch (psi), or 220 kilopascals (kPa), this pressure is applied to every square inch on the inner tire surface. Pressure is always supplied equally to the entire surface of a container. Since air is a gas, the molecules have

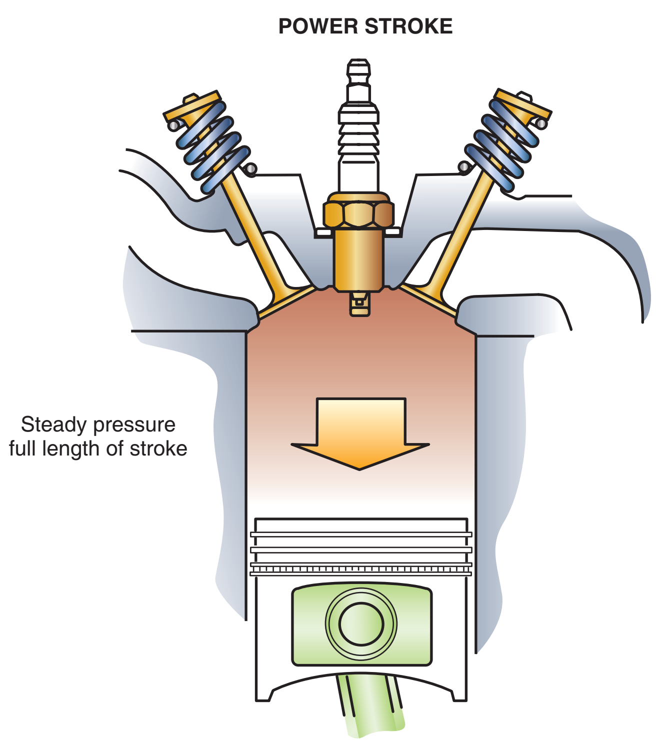

FIGURE 2-14 **Hot, expanding gases push the piston downward and rotate the crankshaft.**

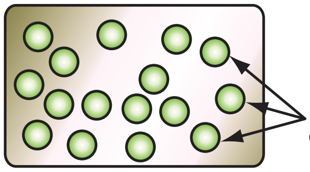

FIGURE 2-15 **Gases can be compressed much like more balls can be placed on a billiard table containing a few balls.**

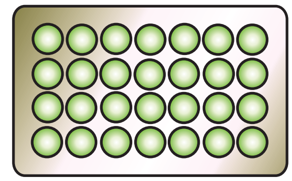

FIGURE 2-16 **Liquids are noncompressible, just as more balls cannot be added to a billiard table with no pockets that is completely filled with balls.**

plenty of space between them. When the tire is inflated, the pressure in the tire increases, and the air molecules are squeezed closer together, or compressed. Under this condition, the air molecules cannot move as freely, but extra molecules of air can still be forced into the tire. Therefore, gases such as air are said to be **compressible**.

Liquids are not compressible.

If a substance is **compressible**, its volume decreases as pressure on the substance increases.

The air in the tire may be compared to a few balls on a billiard table without pockets. If a few more balls are placed on the table, the balls are closer together, but they can still move freely (Figure 2-15).

If the vehicle is driven at high speed, friction between the road surface and the tires heats the tires and the air in the tires. When air temperature increases, the pressure in the tire also increases. Conversely, a temperature decrease reduces pressure.

If 100 cubic feet (2.8 cubic meters) of air is forced into a large truck tire, and the same amount of air is forced into a much smaller car tire, the pressure in the car tire is much greater.

Molecules in a liquid may be compared to a billiard table without pockets that is completely filled with balls. These balls can roll around, but no additional balls can be placed on the table because the balls cannot be compressed. Similarly, liquid molecules cannot be compressed (Figure 2-16).

Liquid Flow

If a tube is filled with billiard balls and the outlet is open, more balls may be added to the inlet. When each ball is moved into the inlet, a ball is forced from the outlet. If the outlet is closed, no more balls can be forced into the inlet (Figure 2-17).

The billiard balls in the tube may be compared to molecules of power steering fluid in the line between the power steering pump and steering gear. Since noncompressible fluid fills the line and gear chamber, the force developed by the pump pressure is transferred through the line to the gear chamber (Figure 2-18).

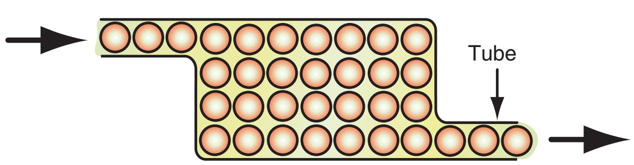

FIGURE 2-17 **Billiard ball movement in a tube filled with balls compared to liquid flow.**

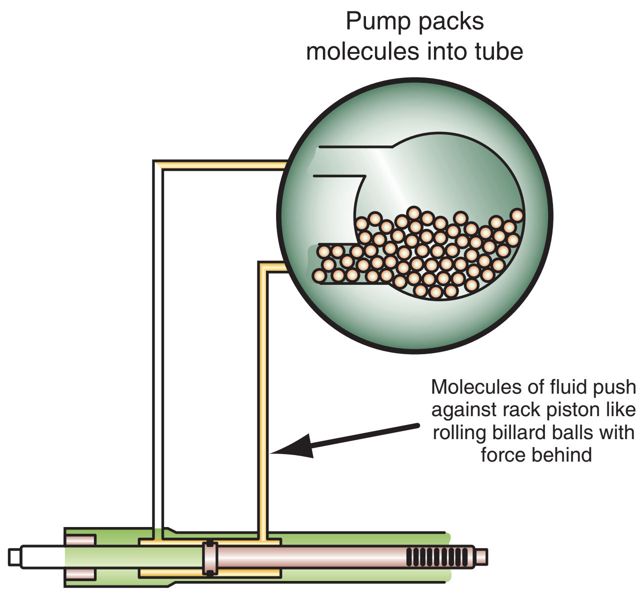

FIGURE 2-18 **Power steering pump pressure supplied to the steering gear chamber.**

Hydraulic Fluid as a Flexible Machine

Hydraulic pressure has the same effect as a mechanical lever, because both of these items can multiply the input force to do more work. If a mechanical lever has a fulcrum at the center point and a 10-pound (lb), or 4.5-kilogram (kg), weight on one end of the lever, 10 lb (4.5 kg) of weight are required on the other end of the lever to force the lever downward and raise the weight on the opposite end. If the lever is 5 ft long and the fulcrum is placed 1 ft from the weight to be lifted, the lever has a 4 to 1 mechanical advantage. Under this condition, 2.5 lb (1.1 kg) of weight are required on the other end of the lever to lift the 10-lb (4.5 kg) weight (Figure 2-19). Therefore, a mechanical lever multiplies input force and makes it easier to do work.

When the power steering pump pressure supplied to the steering gear chamber is 1,000 psi (7,000 kPa), this pressure is applied to every square inch in the steering gear chamber (Figure 2-20). This pressure applied to the rack piston in the gear chamber acts like a mechanical lever and helps move the rack piston. Since the rack is connected through steering linkages and arms to the front wheels, the force on the rackpiston helps the driver move the front wheels to the left or right during a turn (Figure 2-21).

CAUTION:
Never completely block a pump outlet unless instructed to do so in the vehicle manufacturer's service manual. This action can result in extremely high pump pressure, damaged components, and personal injury.

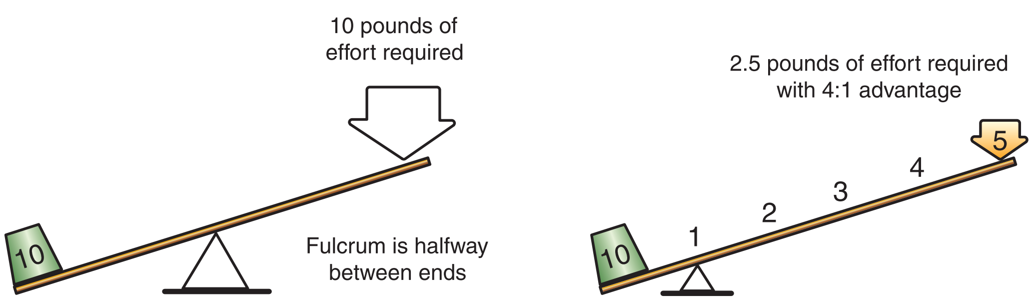

FIGURE 2-19 **A mechanical lever multiplies input force and makes it easier to do work.**

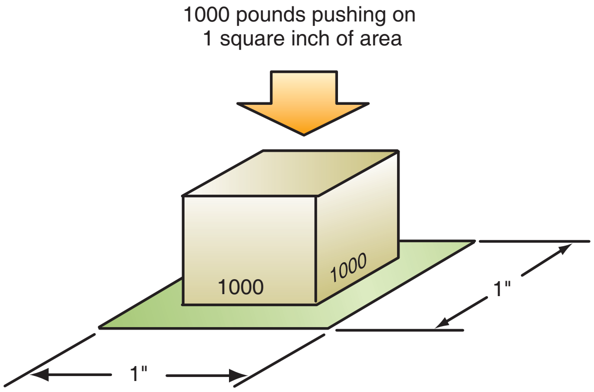

FIGURE 2-20 **Hydraulic pressure is applied equally to every square inch in a container.**

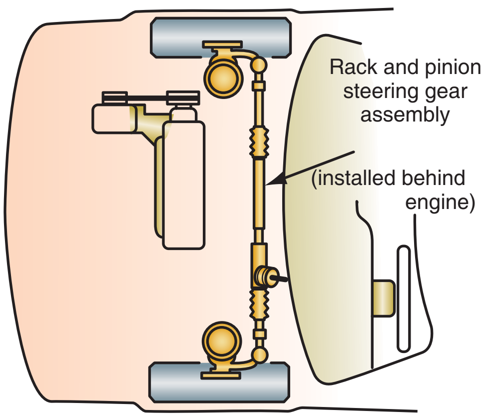

FIGURE 2-21 **Steering gear, linkages, and arms connected to the front wheels.**

Atmospheric Pressure

Since air is gaseous matter with mass and weight, it exerts pressure on the earth's surface. A one-square-inch column of air extending from the earth's surface to the outer edge of the atmosphere weighs 14.7 psi at sea level. Therefore, **atmospheric pressure** is 14.7 psi at sea level (Figure 2-22).

Atmospheric pressure may be defined as the total weight of the earth's atmosphere.

Atmospheric Pressure and Temperature

When air becomes hotter it expands, and this hotter air is lighter compared to an equal volume of cooler air. This hotter, lighter air exerts less pressure on the earth's surface compared to cooler air.

If the temperature decreases, air contracts and becomes heavier. Therefore, an equal volume of cooler air exerts more pressure on the earth's surface compared to hotter air.

An equal volume of hot air weighs less and exerts less pressure on the earth's surface than cold air.

Atmospheric Pressure and Altitude

When you climb above sea level, atmospheric pressure decreases. The weight of a column of air is less at 5,000 feet (1,524 meters) elevation compared to sea level. As altitude continues to increase, atmospheric pressure and weight continue to decrease. At an altitude of several hundred miles above sea level, the earth's atmosphere ends, and there is only vacuum beyond that point.

Atmospheric pressure decreases as altitude increases.

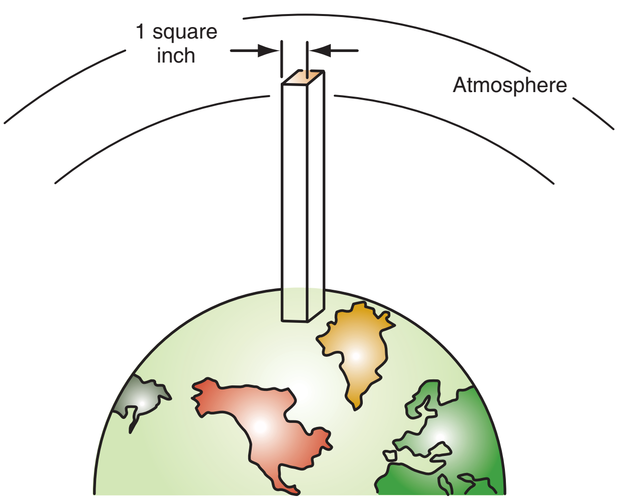

FIGURE 2-22 **A column of air one inch square extending from the earth's surface at sea level to the outer edge of the atmosphere weighs 14.7 lb.**

VACUUM

Atmospheric pressure is generally considered to be 14.7 pounds per square inch (psi) at sea level. Pressures greater than atmospheric pressure may be measured in psi, whereas pressures below atmospheric pressure are measured in **vacuum**, or psi absolute (psia) (Figure 2-23).

Vacuum may be defined as the absence of atmospheric pressure. A vacuum may be called a low pressure because it is a pressure less than atmospheric pressure.

A conventional pressure gauge is used to measure pressures greater than atmospheric pressure. This type of pressure gauge indicates 0 psi at atmospheric pressure, and as the pressure increases it can read up to 15 psi (Figure 2-23). A conventional vacuum gauge indicates 0 in. Hg when atmospheric pressure is applied, and as the vacuum increases this gauge reads from 0 in. Hg to 29.91 inches of mercury (in. Hg), and this may be considered a perfect vacuum. An absolute pressure gauge indicates absolute pressure in pounds per square inch gauge (psig). An absolute pressure gauge indicates 0 at a perfect vacuum, 15 psig at atmospheric pressure, and 30 psig at 15 psi on a conventional pressure gauge. An aneroid barometer reads in. Hg absolute pressure, and thus it reads 0 in. Hg absolute at a perfect vacuum and 29.92 in. Hg absolute when atmospheric pressure is present.

Pressures above atmospheric pressure measured in psi are found in these automotive systems:

1. Fuel
2. Oil
3. Cooling
4. Power steering
5. Air conditioning
6. Turbocharger boost
7. Air springs
8. Gas-filled shock absorbers
9. Brake system during brake application

Pressures below atmospheric pressure measured in inches of vacuum are found in these automotive systems:

1. Manifold vacuum signal
2. Ported vacuum signal above the throttle
3. Carburetor venturi
4. Air-conditioning evacuation

Vacuum could be measured in psi, but inches of mercury (in. Hg) are most commonly used for this measurement. Let us assume that a manometer is partially filled with mercury, and atmospheric pressure is allowed to enter one end of the tube. If vacuum is supplied to the other end of the manometer, the mercury is forced downward by the atmospheric pressure. When this movement occurs, the mercury also moves upward on the side where the

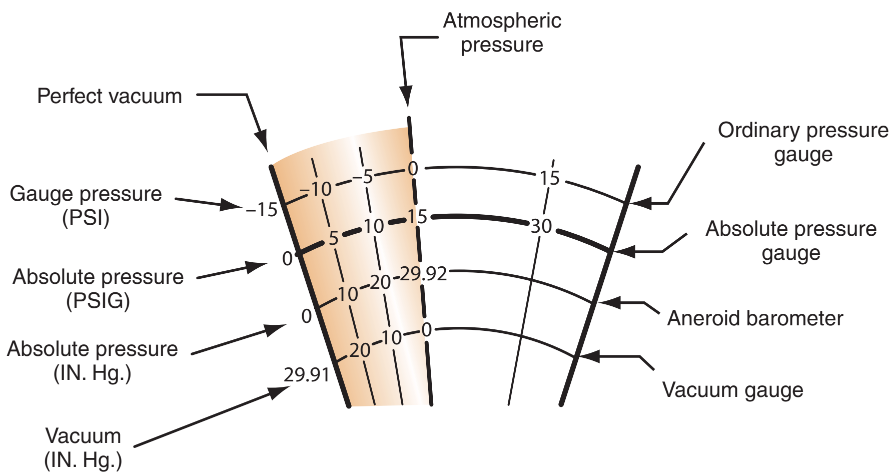

FIGURE 2-23 **Pressure and vacuum scales.**

vacuum is supplied. If the mercury moves downward 10 in., or 25.4 centimeters (cm), where the atmospheric pressure is supplied, and upward 10 in. (25.4 cm) where the vacuum is supplied, 20 in. Hg is supplied to the manometer (Figure 2-24). The highest possible, or perfect, vacuum is approximately 29.9 in. Hg.

Liquids, solids, and gases tend to move from an area of high pressure to a low-pressure area.

Vacuum and atmospheric pressure are used in several automotive systems. For example, atmospheric pressure is present outside the compressor inlet on an electronic air suspension system. When the compressor is running, it creates a vacuum at the inlet and in the compressor cylinder. This pressure difference causes air to move from the atmosphere surrounding the inlet into the cylinder. The compressor develops high pressure at the discharge valve, and this pressure forces air into the air springs when the pressure is lower than at the compressor outlet (Figure 2-25).

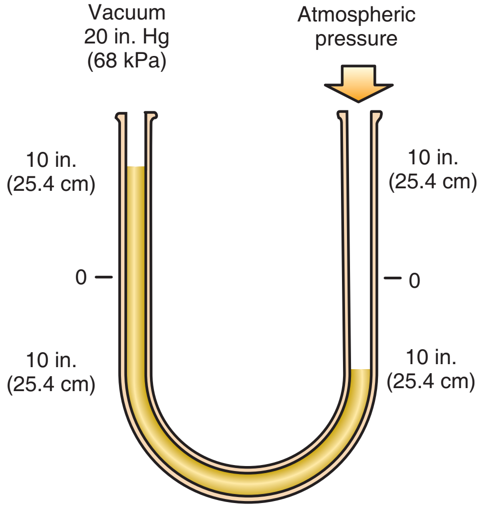

FIGURE 2-24 **A vacuum of 20 in. Hg (68 kPa) supplied to mercury in a manometer.**

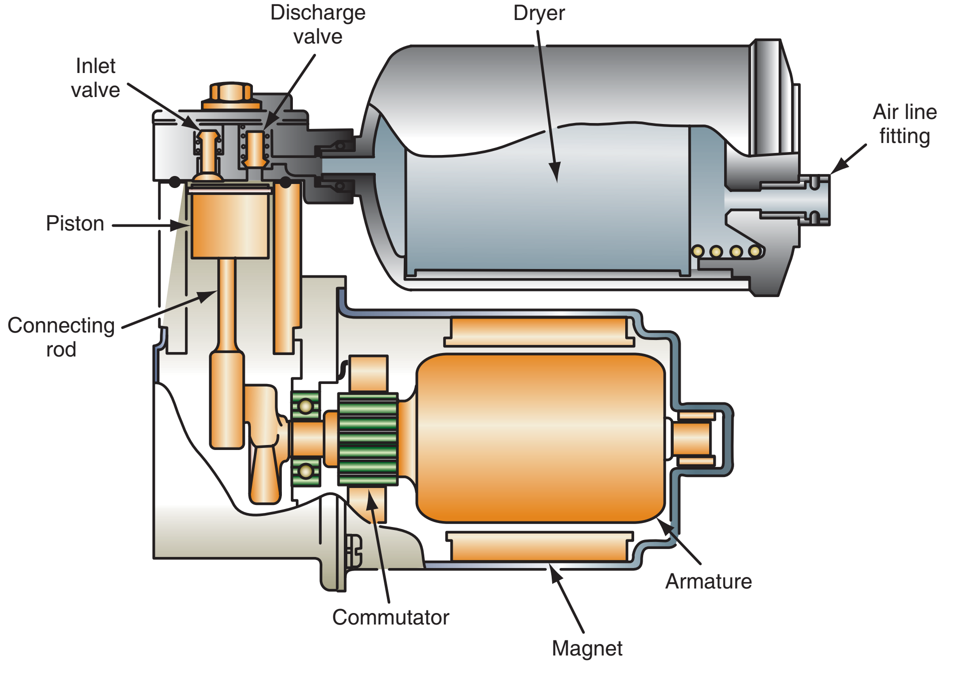

FIGURE 2-25 **An air suspension compressor creates vacuum in the cylinder, and atmospheric pressure at the inlet forces air into the cylinder. The compressor provides high pressure at the discharge valve, which moves air into the air springs.**

Pumps use high and low pressure to move liquids or gases. For example, as a power steering pump rotates, it creates a high pressure at the pump outlet by pumping against a restriction, and a low pressure at the inlet by moving fluid through a restriction. This pressure difference causes fluid to flow through the power steering system.

A venturi may be defined as a narrow area in a pipe through which a liquid or a gas is flowing.

Venturi Principle

If a gas or a liquid is flowing through a pipe and the pipe diameter is narrow in one place, the flow speeds up in the narrow area. This increase in speed causes a lower pressure in the narrow area, which may be defined as a venturi (Figure 2-26). Power steering pumps use a venturi principle to assist in the control of pump pressure.

Technicians must understand basic principles in order to comprehend the complex systems on modern vehicles. When basic principles are mastered, then technicians understand both the reason for, and the result of, these specific service procedures.

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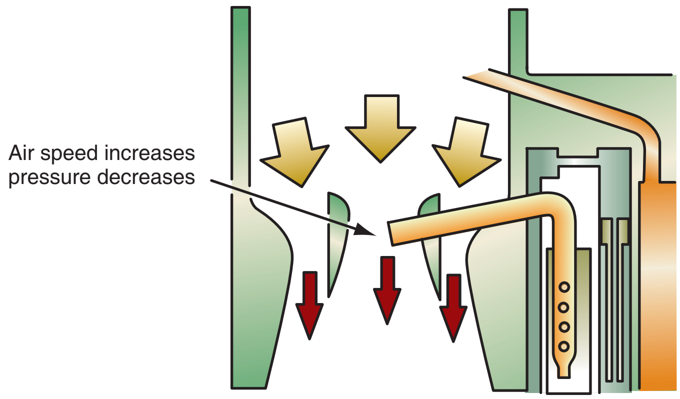


FIGURE 2-26 **A venturi increases air flow speed and produces a vacuum.**

Summary

- Work is the result of applying a force.
- Force is measured in pounds and distance.
- Energy is the ability to do work; there are six basic types of energy.
- Inertia is the tendency of an object at rest to remain at rest, or the tendency of an object in motion to remain in motion.
- An object gains momentum when force overcomes static energy and moves the object.
- Friction is the resistance to motion when one object is moved over another object.
- Mass is a measurement of an object's inertia.
- Weight is a measurement of the earth's gravitational pull on an object.
- Volume is the length, width, and height of a space occupied by an object.
- Power is a measurement for the speed at which work is done.
- A rolling, tilted wheel tends to move in the direction of the tilt.
- If the pivot point at the tire centerline is behind the centerline where the vehicle weight is projected on the road surface, the wheel tends to remain in the straight-ahead position.
- Weight must be distributed equally around the center of wheel rotation viewed from the side to obtain static balance.
- Weight must be distributed equally on both sides of the tire centerline viewed from the front of the tire to maintain proper dynamic balance.
- Torque is a twisting force that does work.
- Atmospheric pressure is the total weight of the earth's atmosphere.
- Vacuum is the absence of atmospheric pressure.

Terms to Know

Atmospheric pressure
Compressible
Dynamic balance
Energy
Force
Friction
Horsepower
Inertia
Mass
Momentum
Static balance
Torque
Vacuum
Volume
Weight
Work

Review Questions

Short Answer Essays

1. Describe Newton's first law of motion, and give an application of this law in automotive theory.
2. Explain Newton's second law of motion, and give an example of how this law is used in automotive theory.
3. Describe Newton's third law of motion, and give an example of how this law applies to an automotive suspension system.
4. Describe six different forms of energy.
5. Describe four different types of energy conversion.
6. Explain the difference between static and dynamic inertia.
7. Explain why a rotating, tilted wheel moves in the direction of the tilt.
8. Explain why the front wheel of a bicycle tends to remain in the straight-ahead position as the bicycle is driven.
9. Define static and dynamic balance.
10. Describe the effect of temperature on the volume of a gas.

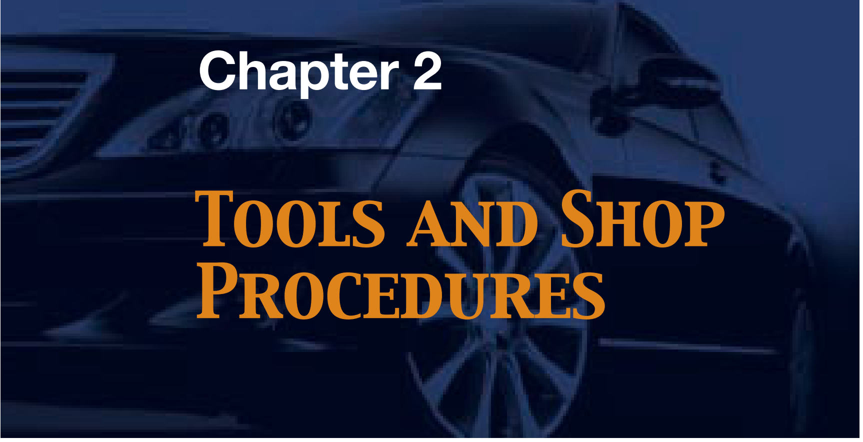
Fill-in-the-Blanks

1. Improper static wheel balance causes wheel _______________ when driving the vehicle.
2. If the tire pivot point is behind the tire and wheel centerline where the vehicle weight is projected against the road surface, the wheel tends to remain in the _______________ position when driving the vehicle.
3. Work is calculated by multiplying _____________ × _______________.
4. Energy may be defined as the ability to do _______________.
5. When one object is moved over another object, the resistance to motion is called _______________.
6. Weight is the measurement of the earth's __________ on an object.
7. Torque is a force that does work with a ___________ action.
8. Power is a measurement for the rate at which _______ is done.
9. To obtain proper dynamic balance, the weight must be distributed equally on both sides of a wheel and tire centerline viewed from the _______________ of the tire.
10. Vacuum is defined as the absence of _______________.

Multiple Choice

1. When an engine is running, the alternator converts:
   A. Thermal energy to mechanical energy.
   B. Electrical energy to mechanical energy.
   C. Chemical energy to electrical energy.
   D. Mechanical energy to electrical energy.
2. Work is accomplished during all of these conditions EXCEPT:
   A. When a mechanical force starts an object in motion.
   B. When a mechanical force is applied to an object, but the object does not move.
   C. When a mechanical force stops an object in motion.
   D. When a mechanical force redirects an object in motion.
3. All these statements about Newton's Laws of Motion are true EXCEPT:
   A. For every action there is an equal and opposite reaction.
   B. A body in motion remains in motion unless an outside force acts on it.
   C. A body's acceleration is directly proportional to the force applied to it.
   D. A body moves in an arc away from the force acting upon the object.

4. Torque is calculated by:
   A. Multiplying the force and the radius from the force to the object.
   B. Dividing the radius by the force.
   C. Adding the force and the distance of force movement.
   D. Subtracting the radius from the force to the object and the weight of the object.
5. When working with gases and liquids:
   A. Gases are not compressible.
   B. Liquids are not compressible.
   C. Temperature does not affect gas volume.
   D. Pressure is applied unevenly to the inside of a container surface.
6. When applying the principles of work and force:
   A. Work is accomplished when force is applied to an object that does not move.
   B. In the metric system the measurement for work is cubic centimeters.
   C. No work is accomplished when an object is stopped by mechanical force.
   D. If a 50-pound object is moved 10 feet, 500 ft-lb of work are produced.
7. All these statements about energy and energy conversion are true EXCEPT:
   A. Thermal energy may be defined as light energy.
   B. Chemical to thermal energy conversion occurs when gasoline burns.
   C. Mechanical energy is defined as the ability to do work.
   D. Mechanical to electrical energy conversion occurs when the engine drives the alternator.
8. A lever is 10 ft (3.0 m) long and the fulcrum is positioned 1 ft (0.304 m) from the end of the lever. A 5 lb (2.26 kg) weight is placed on the end of the lever nearest the fulcrum. The weight required on the opposite end of the lever to lift the 5 lb (2.26 kg) weight is:
   A. 0.368 lb (0.166 kg).
   B. 0.555 lb (0.251 kg).
   C. 0.714 lb (0.323 kg).
   D. 0.748 lb (0.339 kg).
9. A tire-and-wheel assembly that does not have proper dynamic balance has:
   A. Weight that is not distributed equally on both sides of the tire centerline.
   B. Worn tread on the inside edge of the tire.
   C. A tire with improperly positioned steel belts.
   D. Weight that is not distributed equally around the center of the tire and wheel.
10. When a car is driven on the road above 50 mph (80 km/h), the left front tire has a tramping action. The MOST likely cause of this condition is:
   A. Improper left front dynamic wheel balance.
   B. A bent left front wheel rim.
   C. Improper left front static wheel balance.
   D. Improper rim offset.



Chapter 2

Tools and Shop Procedures

Upon completion and review of this chapter, you should be able to:

- Diagnose steering and suspension problems using a basic diagnostic procedure.
- Raise a vehicle with a floor jack and lower the vehicle so it is supported on safety stands.
- Raise a vehicle with a lift.
- Test power steering pump pressure with an appropriate pressure gauge and valve assembly.
- Measure ball joint wear with a dial indicator designed for this purpose.
- Remove and replace a coil spring on a strut using a coil spring compressor tool.
- Use a tire changer to dismount and mount a tire.
- Use a scan tool to diagnose a computer-controlled suspension system.
- Balance tire-and-wheel assemblies with an electronic wheel balancer.
- Perform a four wheel alignment with a computer wheel aligner.
- Fulfill employee obligations when working in the shop.
- Accept job responsibility for each job completed in the shop.
- Describe the ASE automotive technician testing and certification process including the eight areas of certification.

Using Suspension and Steering Equipment

Learn to use equipment properly the first time. When improper procedures are learned and become a habit, it is more difficult to break these wrong habits. Using service and test equipment will help you to work more safely and efficiently, and in the long term, this should improve your income. We will discuss the proper use of some of the most common service and test equipment used by suspension and steering technicians.

Measuring Systems

Two systems of weights and measures are commonly used in the United States. One system is the **U.S. customary (USC) system**, which is commonly referred to as the English system. Well-known measurements for length in the USC system are the inch, foot, yard, and mile. In this system, the quart and gallon are measurements for volume; ounce, pound, and ton are measurements for weight. A second system of weights and measures is called the **international system (SI)**, also known as the metric system.

In the USC system, the basic linear measurement is the yard; in the metric system, it is the meter. Each unit of measurement in the metric system is related to the other metric units by a factor of 10. Thus, every metric unit can be multiplied or divided by 10 (or 100 or 1,000) to obtain larger units (multiples) or smaller units (submultiples). For example, the meter maybe divided by 100 to obtain centimeters (1/100 meter) or by 1,000 to obtain millimeters (1/1,000 meter).

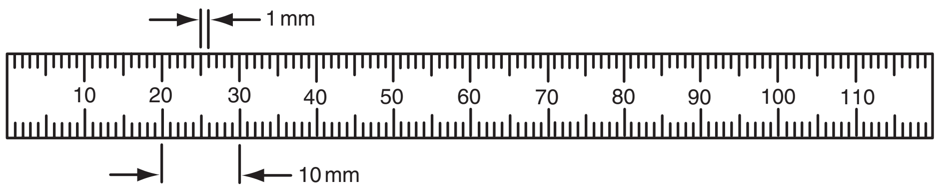


FIGURE 2-1 **Metric tape graduated in millimeters.**

The U.S. government passed the Metric Conversion Act in 1975 in an attempt to move American industry and the general public to accept and adopt the metric system. The automotive industry has adopted the metric system, and in recent years most bolts, nuts, and fittings on vehicles have been changed to metric. During the early 1980s some vehicles had a mix of English and metric bolts. Imported vehicles have used the metric system for many years. Although the automotive industry has changed to the metric system, the general public in the United States has been slow to convert from the USC system to the metric system. One of the factors involved in this change is cost. What would it cost to change every highway distance and speed sign in the United States to read kilometers? Probably hundreds of millions, or even billions, of dollars.

Service technicians must be able to work with both the USC and the metric system. One meter (m) in the metric system is equal to 39.37 inches (in.) in the USC system. A metric tape measure may be graduated in millimeters, and 10 millimeters = 1 centimeter (Figure 2-1).

Some common equivalents between the metric and USC systems are:

1 meter (m) = 39.378 inches
1 centimeter (cm) = 0.3937 inch
1 millimeter (mm) = 0.03937 inch
1 inch = 2.54 centimeter
1 inch = 25.4 millimeter

In the USC system, phrases such as 1/8 of an inch are used for measurements. The metric system uses a set of prefixes. For example, in the word kilometer the prefix kilo means 1,000, indicating that there are 1,000 meters in a kilometer. Common prefixes in the metric system include:

NAME	SYMBOL	MEANING
mega	M	one million
kilo	k	one thousand
hecto	h	one hundred
deca	da	ten
deci	d	one tenth of
centi	c	one hundredth of
milli	m	one thousandth of
micro	μ	one millionth of

Measurement of Mass

In the metric system mass is measured in grams, kilograms, or tonnes: 1,000 grams (g) = 1 kilogram (kg). In the USC system mass is measured in ounces, pounds, or tons. When converting pounds to kilograms, 1 pound = 0.453 kilograms.

Measurement of Length

In the metric system length is measured in millimeters, centimeters, meters, or kilometers: 10 millimeters (mm) = 1 centimeter (cm). In the USC system length is measured in inches, feet, yards, or miles.

When distance conversions are made between the two systems some of the following conversion factors are used:

1 inch = 25.4 millimeters
1 foot = 30.48 centimeters
1 yard = 0.91 meters
1 mile = 1.60 kilometers

Measurement of Volume

In the metric system volume is measured in milliliters, cubic centimeters, and liters: 1 cubic centimeter = 1 milliliter. If a cube has a length, depth, and height of 10 centimeters (cm), the volume of the cube is 10 cm $\times$ 10 cm $\times$ 10 cm = 1,000 cm^3 = 1 liter. When volume conversions are made between the two systems, 1 cubic inch = 16.38 cubic centimeters. If an engine has a displacement of 350 cubic inches, 350 $\times$ 16.38 = 5,733 cubic centimeters, and 5,733 ÷ 1,000 = 5.7 liters.

Basic Diagnostic Procedure

One of the most important parts of a technician's job is diagnosing automotive problems. Each year more vehicle systems are controlled by increasingly sophisticated electronic systems, and this makes accurate diagnosis even more important.

The following basic diagnostic procedure may be used to diagnose various automotive problems:

1. Be absolutely sure the problem is identified. Obtain all the information you can from the customer; for example, politely ask the customer to describe the exact symptoms of the problem. Ask the customer at what vehicle speed, engine temperature, and atmospheric temperature the problem occurs. From your discussion, find out when, where, and how the problem occurs.
2. Verify the problem. If necessary, road test the vehicle under the same conditions as the customer described to verify the problem.
3. Think of the possible causes of the problem based on your own experience in diagnosing similar problems on other vehicles.
4. Consult original equipment manufacturer (OEM) or generic technical service bulletin (TSB) information regarding service procedures, parts replacement, or computer reprogramming that are designed to correct the problem.
5. Perform the necessary diagnostic tests to locate the exact cause of the complaint. Always begin the diagnostic tests with the quickest, easiest test, and if the problem is not located, proceed with the more complicated, time-consuming tests. During your diagnosis watch for other problems with the vehicle that may give trouble in the near future. If there are any other potential problems such as worn belts and radiator hoses, advise the customer about them and attempt to obtain the customer's approval to repair these problems. If the customer does not approve the repair of these potential problems, describe them on the work order. If we repair a car based on a complaint on a customer's vehicle, and two weeks later the customer brings the vehicle back with another serious complaint, the customer may assume that the repairs were not completed thoroughly.
6. After the cause of the complaint is definitely located, advise the customer about the extent and cost of the repairs. After the customer approves the necessary repairs, perform the appropriate service work on the vehicle.
7. Road test the vehicle if necessary to be sure the customer's complaint is eliminated.

Suspension and Steering Tools

CUSTOMER CARE: Some automotive service centers have a policy of performing some minor service as an indication of their appreciation to the customer. This service may include cleaning all the windows and/or vacuuming the floors before the car is returned to the customer.

Although this service involves more labor costs for the shop, it may actually improve profits over a period of time. When customers find their windows cleaned and/or the floors vacuumed, it impresses them with the quality of work you do and the fact you care about their vehicle. They will likely return for service, besides telling their friends about the quality of service your shop performs.

CAUTION: Do not hit the seal case with a hammer. This action will damage the seal.

CAUTION: Always be sure the seal goes into the housing squarely and evenly. If the seal does not go squarely into the housing, the outer seal case may be distorted, and this condition may cause an oil leak around the seal housing.

SERVICE TIP: When installing a seal, the garter spring must face toward the flow of lubricant.

Seal drivers are available in various diameters to fit squarely against the outside edge of different-size seals. The seal driver handle is tapped with a soft hammer to install the seal.

Seal Drivers

WARNING: When using any suspension and steering tools, the vehicle manufacturer's recommended procedure in the service manual must be followed. Improper use of tools may lead to personal injury.

Seal drivers are designed to fit squarely against the seal case and inside the seal lip. A soft hammer is used to tap the seal driver and drive the seal straight into the housing. Some tool manufacturers market a seal driver kit with drivers to fit many common seals (Figure 2-2).

Bearing Pullers

A variety of **bearing pullers** are available to pull different sizes of bearings in various locations (Figure 2-3). Some bearing pullers are slide-hammer-type, whereas others are screw-type.

Axle Pullers

Axle pullers are used to pull rear axle shafts in rear-wheel-drive vehicles. Most rear axle pullers are slide-hammer-type (Figure 2-4).

FIGURE 2-2 **Seal drivers.**

FIGURE 2-3 **Bearing pullers.**

FIGURE 2-4 **Axle puller.**

Bearing pullers are designed to fit over the outer diameter of the bearing or through the center opening in the bearing, pulling the bearing from its mounting shaft.

Axle pullers are usually slide-hammer type. These pullers attach to the axle studs to remove the axle.

Stethoscope

A **stethoscope** is a mechanical device that amplifies sound and diagnoses the source of noises such as bearing noise. The stethoscope pickup is placed on the suspected noise source, and the ends of the two arms are placed in the technician's ears (Figure 2-5). Electronic stethoscopes provide improved sound amplification compared with mechanical stethoscopes and can locate the causes of mechanical noises, air leaks, and wind whistles.

A **stethoscope** is placed in the technician's ears, and the pickup is placed on or near the suspected noise source to diagnose noise problems.

Front Bearing Hub Tool

Front bearing hub tools are designed to remove and install front wheel bearings on front-wheel-drive cars (Figure 2-6). These bearing hub tools are usually designed for a specific make of vehicle.

FIGURE 2-5 **Stethoscope.**

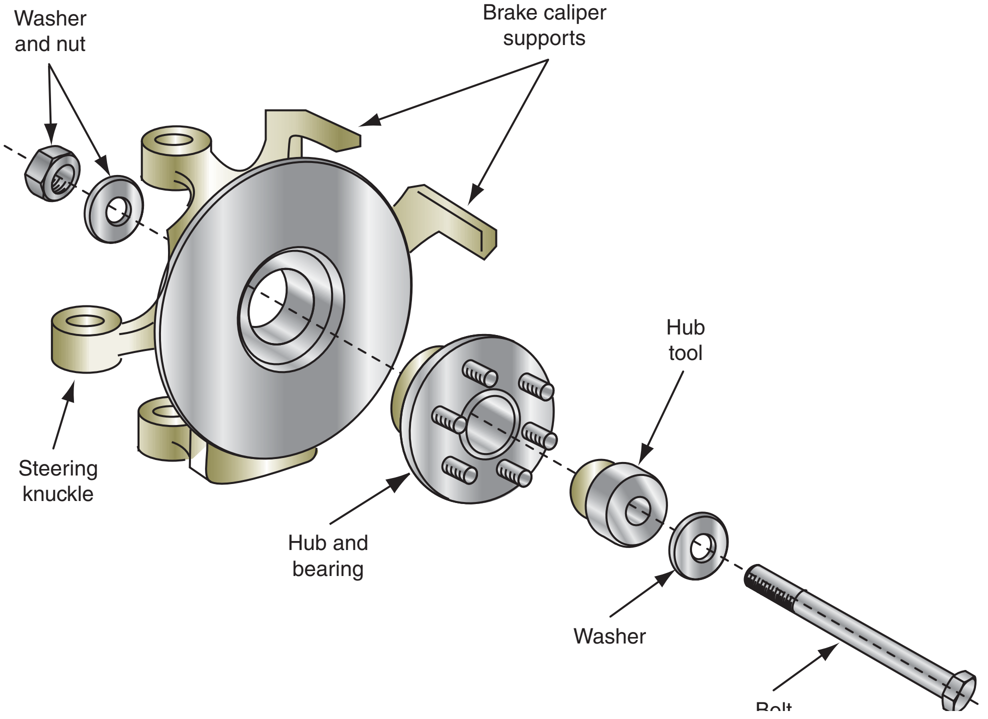


FIGURE 2-6 **Front bearing hub tool.**

SERVICE TIP:
Dial indicators must be kept clean and dry for accuracy and long life.

Dial Indicator

Dial indicators are used for measuring in many different locations. In the suspension and steering area, dial indicators are used for measurements, such as tire runout and ball joint movement (Figure 2-7). Dial indicators have many different attaching devices to connect the indicator to the component to be measured.

Tire Tread Depth Gauge

A **tire tread depth gauge** measures tire tread depth. This measurement should be taken at three or four locations around the tire's circumference. The lowest reading is considered to be the tread depth (Figure 2-8). Do not place the gauge tip on a wear indicator bar. This gauge is essential when making tire warranty adjustments.

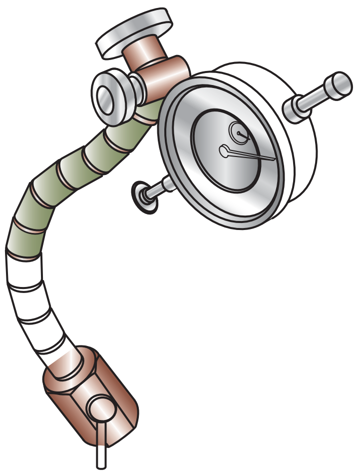


FIGURE 2-7 **Dial indicator designed for ball joint measurement.**

FIGURE 2-8 **Tire tread depth gauge.**

Tire Changer

A **tire changer** is operated pneumatically to dismount and mount tires from the rims.

WARNING: Never operate a tire changer until you are familiar with its operation because this may lead to serious personal injury. Your instructor will explain and demonstrate the operation of this equipment. You should read the equipment operator's manual and use this equipment under the instructor's supervision until you are familiar with it.

Tire changers are used to dismount and mount tires (Figure 2-9). These changers may be used on most common tire sizes. A wide variety of tire changers are available, and each one

FIGURE 2-9 **Typical tire changer.**

FIGURE 2-10 **Typical electronic wheel balancer.**

operates differently. Always follow the procedure in the equipment operator's manual and the directions provided by your instructor.

Wheel Balancer

WARNING: Using a wheel balancer before you are familiar with its operation may result in serious personal injury and property damage.

Electronic wheel balancers indicate the required weight location on the rim to obtain proper static and dynamic wheel balance.

Electronic wheel balancers are used in most automotive repair shops (Figure 2-10). Do not attempt to use this equipment until you have studied wheel balance theory. Your instructor will explain and demonstrate the use of this equipment before you attempt to use it. This equipment should be used under the supervision of your instructor until you are familiar with it.

Machinist's Rule

A **machinist's rule** performs many accurate measurements in the shop. Most machinist's rules are graduated in inches and millimeters (Figure 2-11).

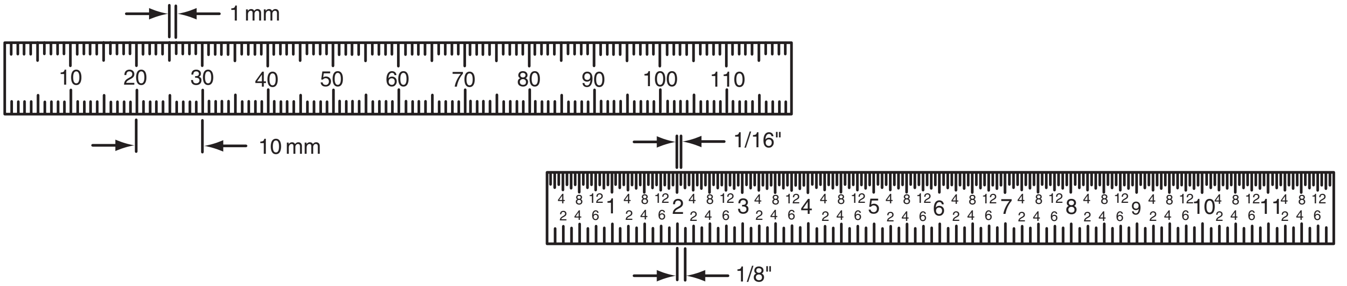


FIGURE 2-11 **Graduations on a typical machinist's rule.**

Air Chisel or Hammer

An air chisel is an electrically operated tool to which various chisels, cutters, and punches may be attached to complete cutting and riveting jobs. The air hammer operates the attached tool with a very fast back-and-forth action (Figure 2-12). Different tools that may be attached to the air chisel are illustrated in Figure 2-13.

FIGURE 2-12 **Air chisel.**

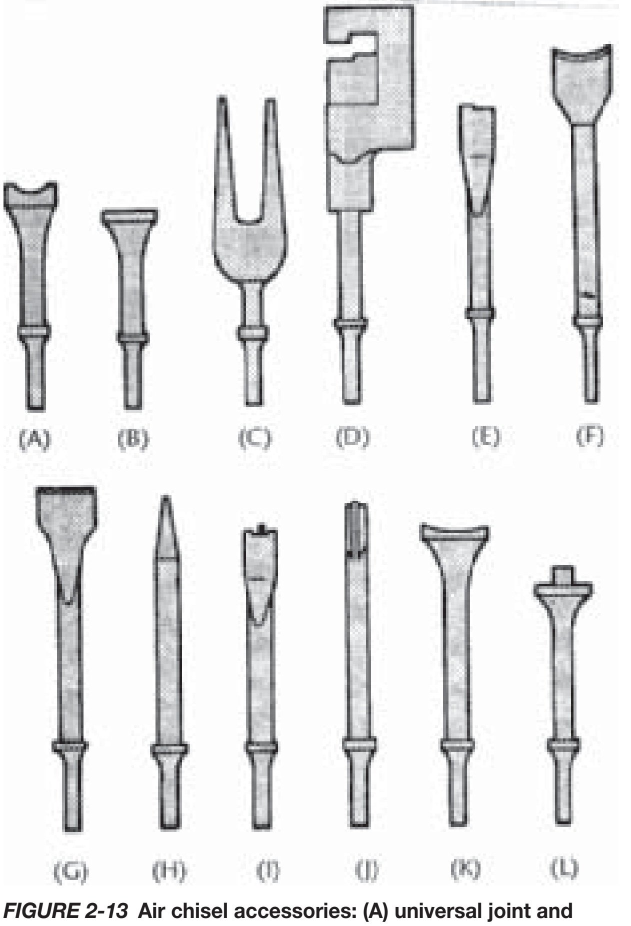


FIGURE 2-13 **Air chisel accessories: (A) universal joint and tie-rod end tool, (B) smoothing hammer, (C) ball joint separator, (D) panel crimper, (E) shock absorber chisel, (F) tailpipe cutter, (G) scraper, (H) tapered punch, (I) edging tool, (J) rubber bushing splitter, (K) bushing remover, and (L) busing installer.**

WARNING: **Always be sure the tool being used is properly attached to the air chisel. Improper tool attachment may result in serious personal injury.**

Ball Joint Removal and Installation Tools

Ball joint removal and installation tools remove and install pressed-in ball joints on front suspension systems (Figure 2-14). The size of the removal and pressing tool adapter must match the size of the ball joint.

Tie Rod End and Ball Joint Puller

Some car manufacturers recommend a **tie rod end and ball joint puller** to remove tie rod ends and pull ball joint studs from the steering knuckle (Figure 2-15).

Control Arm Bushing Tools

A variety of **control arm bushing tools** are available to remove and replace control arm bushings. The bushing removal and installation tool must match the size of the control arm bushing (Figure 2-16).

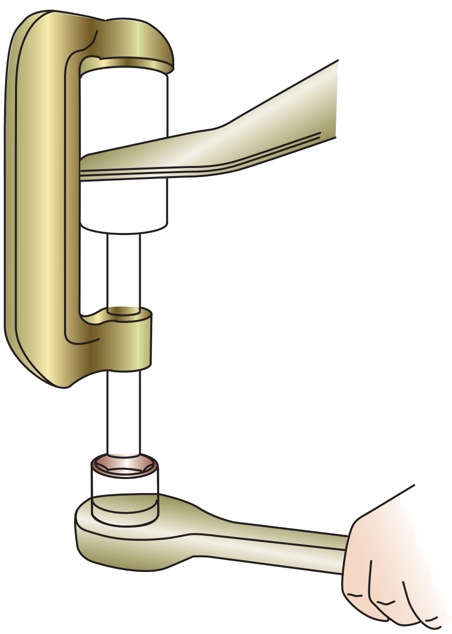


FIGURE 2-14 **Ball joint removal and installation tool.**

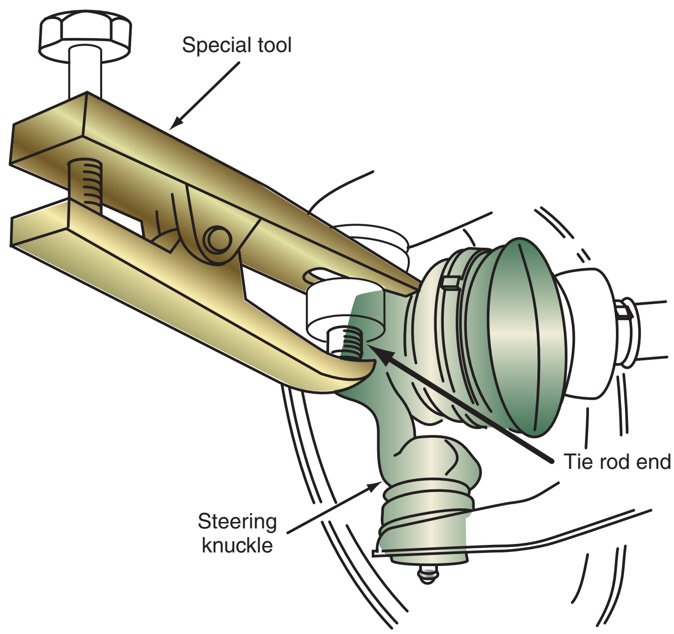


FIGURE 2-15 **Tie rod end and ball joint puller.**

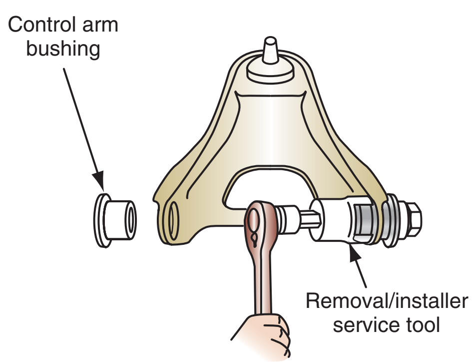


FIGURE 2-16 **Control arm bushing removal and replacement tools.**

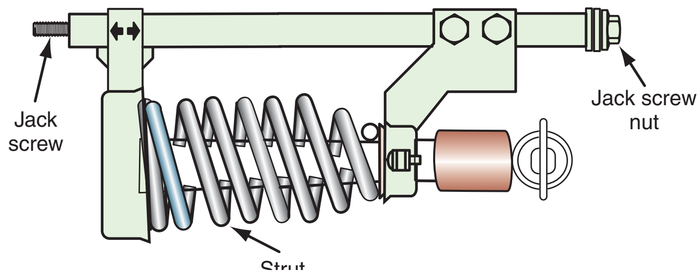


FIGURE 2-17 **MacPherson strut coil spring compressor tool.**

Coil Spring Compressor Tool

WARNING: There is a tremendous amount of energy in a compressed coil spring. Never disconnect any suspension component that will suddenly release this tension because this may result in serious personal injury and vehicle or property damage.

CAUTION: The vehicle manufacturer's and equipment manufacturer's recommended procedures must be followed for each type of spring compressor tool.

Many types of **coil spring compressor tools** are available to the automotive service industry (Figure 2-17). These tools compress the coil spring and hold it in the compressed position while removing the strut from the coil spring or performing other suspension work. Each type of front suspension system requires a different type of spring compressor tool. The vehicle manufacturer's and equipment manufacturer's recommended procedure must be followed.

Power Steering Pressure Gauge

WARNING: The power steering pump delivers extremely high pressure during the pump pressure test. Always follow the recommended test procedure in the vehicle manufacturer's service manual to avoid personal injury during this test.

A **power steering pressure gauge** is used to test the power steering pump pressure (Figure 2-18). Because the power steering pump delivers extremely high pressure during this test, the recommended procedure in the vehicle manufacturer's service manual must be followed.

FIGURE 2-18 **Power steering pressure gauge.**

FIGURE 2-19 **Pitman arm puller.**

Pitman Arm Puller

WARNING: Never strike a puller with a hammer when it is installed and tightened because this may result in personal injury.

A **pitman arm puller** is a heavy-duty puller that removes the pitman arm from the pitman shaft (Figure 2-19).

Vacuum Hand Pump

A **vacuum hand pump** creates a vacuum to test vacuum-operated components and hoses (Figure 2-20).

Torque Wrenches and Torque Sticks

A torque wrench is required to tighten fasteners to a specified torque. Tightening fasteners to the specified torque is extremely important. If fastener torque is less than specified, the component retained by the fastener(s) may loosen, resulting in severe component or vehicle damage. When fasteners are tightened to a torque above the specified value, the component may become warped, resulting in improper component operation. Torque wrenches can be beam, click, or dial-type (Figure 2-21). A beam-type torque wrench bends as torque

FIGURE 2-20 **Vacuum hand pump.**

FIGURE 2-21 **Various types of torque wrenches.**

is applied, and a beam on the wrench points to the torque applied on a scale attached to the wrench handle. On a click-type torque wrench, the handle is rotated to set the specified torque on a scale adjacent to the handle. When the fastener is tightened to the torque setting, the torque wrench provides an audible click. On a dial-type torque wrench, the torque applied to the fastener is indicated on the dial. Digital-type torque wrenches that indicate the torque reading on a digital display are also available.

Some tool manufactures provide torque sticks for tightening fasteners to the specified torque with an impact wrench. One end of the torque stick has a ½ in. drive opening, and a socket is attached to the opposite end. A spring steel, heat-treated shaft is connected between the ½ in. drive opening and the socket end of the torque stick. Torque sticks are calibrated to twist at a specific torque with each blow of an impact wrench, and thus prevent further tightening of the fastener. Torque sticks are available in various USC and metric sizes and are usually sold in color-coded sets. The torque stick color indicates the specified torque at which they twist. For example, a yellow torque stick twists at 65 ft. lbs. Some torque sticks are a ½ in. extension that fits between the impact wrench drive and a thin-wall impact socket (Figure 2-22).

SERVICE TIP: Using a torque stick allows the use of an impact wrench when tightening fasteners, and this speeds up the service operation. However, the use of torque sticks may not be as accurate as using a torque wrench. It is a good practice to double check the accuracy of a torque stick by checking the fastener torque with a torque wrench after it is tightened with a torque stick.

Turning Radius Gauge

Turning radius gauge turntables are placed under the front wheels during a wheel alignment. The top plate in the turning radius gauge rotates on the bottom plate to allow the front wheels to be turned during a wheel alignment. A degree scale and a pointer on the gauge indicate the number of degrees the front wheels are turned (Figure 2-23). If the car has four-wheel steering (4WS), the turning radius gauges are also placed under the rear wheels during a wheel alignment.

Plumb Bob

A **plumb bob** is a metal weight with a tapered end (Figure 2-24). This weight is suspended on a string. Plumbers use a plumb bob to locate pipe openings directly below each other at the top and bottom of partitions. Some vehicle manufacturers recommend checking vehicle frame measurements with a plumb bob.

Tram Gauge

A **tram gauge** is a long, straight graduated bar with an adjustable pointer at each end (Figure 2-25). The tram gauge performs frame and body measurements.

FIGURE 2-22 **Torque stick.**

FIGURE 2-23 **Turing radius gauge.**

FIGURE 2-24 Plumb bob.

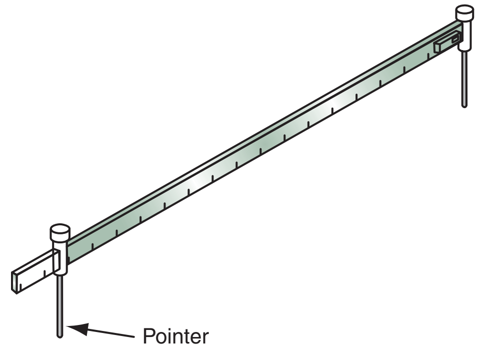


FIGURE 2-25 Tram gauge.

Magnetic Wheel Alignment Gauge

Each **magnetic wheel alignment gauge** contains a strong magnet that holds the gauge securely on the front wheel hubs. The magnetic wheel alignment gauge measures some of the front suspension alignment angles (Figure 2-26).

SERVICE TIP:
Magnetic wheel alignment gauge mounting surfaces must be clean with no metal burrs.

Rim Clamps

When the wheel hub is inaccessible to the magnetic alignment gauge, an adjustable **rim clamp** may be attached to each front wheel. The magnetic gauges may be attached to the rim clamp (Figure 2-27). Rim clamps are also used on computer wheel aligners.

Brake Pedal Jack

A **brake pedal jack** must be installed between the front seat and the brake pedal to apply the brakes while checking some front wheel alignment angles (Figure 2-28).

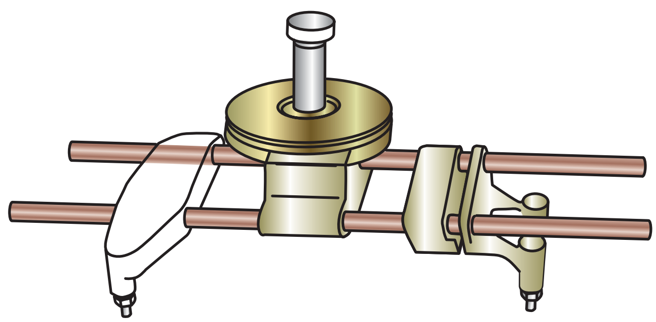


FIGURE 2-27 Rim clamps.

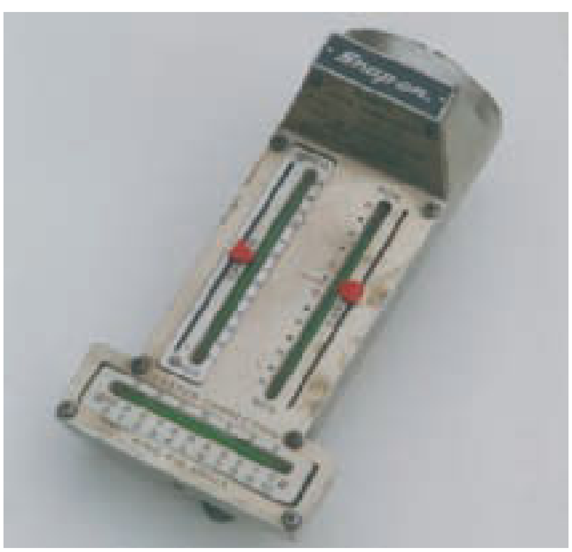


FIGURE 2-26 Magnetic wheel alignment gauge.

FIGURE 2-28 Brake pedal jack.

FIGURE 2-29 **Tie rod sleeve adjusting tool.**

FIGURE 2-30 **Steering wheel locking tool.**

Tie Rod Sleeve Adjusting Tool

A **tie rod sleeve adjusting tool** rotates the tie rod sleeves and performs some front wheel adjustments (Figure 2-29).

Steering Wheel Locking Tool

A **steering wheel locking tool** locks the steering wheel while performing some front suspension service (Figure 2-30).

Toe Gauge

A **toe gauge** is a long, straight, graduated bar that measures front wheel toe (Figure 2-31).

Track Gauge

Some **track gauges** use a fiber-optic alignment system to measure front wheel toe and to determine if the rear wheels are tracking directly behind the front wheels. The front and rear fiber-optic gauges may be connected to the wheel hubs or to rim clamps attached to the wheel rims (Figure 2-32). A remote light source in the main control is sent through fiber-optic cables to the wheel gauges. A strong light beam between the front and rear wheel units informs the technician if the rear wheel tracking is correct.

Computer Four Wheel Aligner

Many automotive shops are equipped with a **computer four wheel aligner** (Figure 2-33). These wheel aligners perform all front and rear wheel alignment angles quickly and accurately.

CAUTION:
Do not use anything except a tie rod adjusting tool to adjust the tie rod sleeves. Tools, such as a pipe wrench, will damage the sleeves.

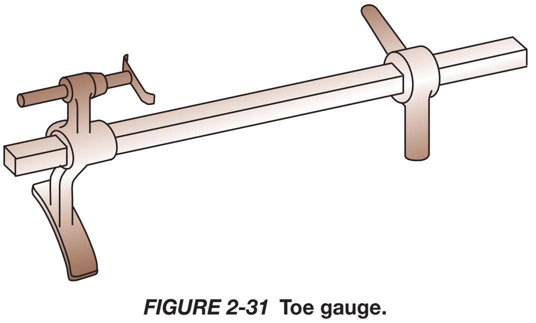


FIGURE 2-31 **Toe gauge.**

FIGURE 2-32 **Fiber optic track and toe gauge.**

FIGURE 2-33 **Computer wheel aligner.**

Scan Tool

A variety of **scan tools** are available for diagnosing automotive computer systems (Figure 2-34). These testers obtain fault codes and perform other diagnostic functions on computer-controlled suspension systems.

Bench Grinder

WARNING: Always wear a face shield when using a bench grinder. Failure to observe this precaution may cause personal injury.

WARNING: When grinding small components on a grinding wheel, wire brush wheel, or buffing wheel, always hold these components with a pair of vise grips to avoid injury to fingers and hands.

WARNING: Grinding and buffing wheels on bench grinders must be mounted on the grinder according to the manufacturer's instructions. Grinding and buffing wheels must be retained with the manufacturer's specified washers and nuts, and the retaining nuts must be tightened to the specified torque. Personal injury may occur if grinding and buffing wheels are not properly attached to the bench grinder.

Bench grinders usually have a grinding wheel and a wire wheel brush driven by an electric motor (Figure 2-35). The grinding wheel may be replaced with a grinding disc containing several layers of synthetic material (Figure 2-36). A buffing wheel may be used in place of the wire wheel brush. The grinding wheel may be used for various grinding jobs and deburring. A buffing wheel is most commonly used for polishing. Most bench grinders have grinding wheels and wire brush wheels that are 6 to 10 in. (15.24 to 25.4 cm) in diameter. Bench grinders must be securely bolted to the workbench.

FIGURE 2-34 **Scan tool for diagnosing computer-controlled suspension systems.**

FIGURE 2-35 **Bench grinder.**

FIGURE 2-36 **Bench grinder accessories.**

Hydraulic Pressing and Lifting Equipment

Hydraulic Press

> A **hydraulic press** uses a hydraulic cylinder and ram to remove and install precision-fit components from their mounting location.

WARNING: When operating a hydraulic press, always be sure that the components being pressed are supported properly on the press bed with steel supports. Improperly supported components may slip, resulting in personal injury.

WARNING: When using a hydraulic press, never operate the pump handle if the pressure gauge exceeds the maximum pressure rating of the press. If this pressure maximum is exceeded, some part of the press may suddenly break, causing severe personal injury.

WARNING: Be sure the safety cage is in place around the press to prevent personal injury.

When two components have a tight precision fit between them, a hydraulic press is used to either separate these components or press them together. The hydraulic press rests on the shop floor, and an adjustable steel-beam bed is retained to the lower press frame with heavy steel pins. A hydraulic cylinder and ram is mounted on the top part of the press with the ram facing downward toward the press bed (Figure 2-37). The component being pressed is placed on the press bed with appropriate steel supports. A hand-operated hydraulic pump is mounted on the side of the press. When the handle is pumped, hydraulic fluid is forced into the cylinder, and the ram is extended against the component on the press bed to complete the pressing operation. A pressure gauge on the press indicates the pressure applied from the hand pump to the cylinder. The press frame is designed for a certain maximum pressure, and this pressure must not be exceeded during hand pump operation.

Floor Jack

WARNING: The maximum lifting capacity of the floor jack is usually written on the jack decal. Never lift a vehicle that exceeds the jack lifting capacity. This action may cause the jack to break or collapse, resulting in vehicle damage or personal injury.

A **floor jack** uses hydraulic pressure supplied to a hydraulic cylinder, ram, and lift pad to lift one end or one corner of a vehicle.

A floor jack is a portable unit mounted on wheels. The lifting pad on the jack is placed under the chassis of the vehicle, and the jack handle is operated with a pumping action (Figure 2-38), forcing fluid into a hydraulic cylinder in the jack. Then this cylinder extends to force the jack lift pad upward and lift the vehicle. Always be sure that the lift pad is positioned securely under one of the car manufacturer's recommended lifting points. To release the hydraulic pressure and lower the vehicle, the handle or release lever must be turned slowly. Do not leave the jack handle where someone can trip over it.

FIGURE 2-37 **Hydraulic press.**

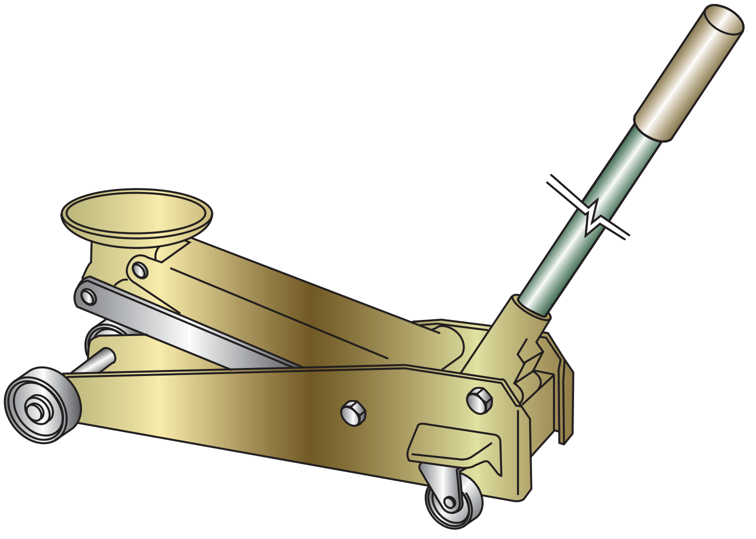


FIGURE 2-38 **Hydraulic floor jack.**

Vehicle Lift (Hoist)

A **vehicle lift** raises a vehicle so the technician can work under it. The lift arms must be placed under the car manufacturer's recommended lifting points prior to raising a vehicle. Twin posts are used on some lifts, whereas other lifts have a single post (Figure 2-39). Some lifts have an electric motor, which drives a hydraulic pump to create fluid pressure and force the lift upward. Other lifts use air pressure from the shop air supply to force the lift upward. If shop air pressure is used, it is applied to fluid in the lift cylinder. A control lever or switch is placed near the lift, which supplies shop air pressure to the lift cylinder and turns on the lift pump motor. Always be sure that the safety lock is engaged after the lift is raised. When the safety lock is released, a release lever is operated slowly to lower the vehicle.

CAUTION: Always be sure that the lift arms are securely positioned under the car manufacturer's recommended lifting points before raising the vehicle. These lifting points are shown in the service manual. If the lift arms are not positioned on the proper lift points, chassis components may be damaged, or the vehicle may slide off the lift, resulting in vehicle damage and/or personal injury.

Using a Floor Jack and Safety Stands

A floor jack is often used to raise a vehicle off the floor. The vehicle is then lowered onto **safety stands** to allow service work to be performed under the vehicle (Figure 2-40).

Follow this procedure to lift a vehicle with a floor jack and then support it on safety stands:

1. Check the weight ratings of the floor jack and the safety stands; be sure these ratings exceed the weight to be lifted and supported.

WARNING: If the vehicle weight to be lifted and supported exceeds the weight rating of the floor jack or safety stands, the floor jack or safety stands may collapse, allowing the vehicle to drop suddenly, which may cause personal injury and/or vehicle damage.

A **vehicle lift** may be called a hoist.

2. Be sure the vehicle is parked on a level surface. Place wheel blocks behind the rear wheels of the vehicle if you are lifting the front end. Place these wheel blocks in front of the front wheels if you are lifting the rear end.
3. Determine the vehicle manufacturer's specified lift point from the vehicle service manual, and position the floor jack lift pad under this lift point. Pump the floor jack handle until the lift pad contacts the lift point on the vehicle.

Safety stands may be called jack stands.

FIGURE 2-39 **Vehicle lifts are used to raise a vehicle.**

FIGURE 2-40 **Typical safety stands.**

CAUTION: The maximum capacity of the vehicle lift is placed on an identification plate. Never lift a vehicle that is heavier than the maximum capacity of the lift. Lifting a vehicle with a weight greater than the lift weight rating may bend the lift or cause the vehicle to slip off the lift, resulting in vehicle damage and/or personal injury.

CAUTION: Lifting or supporting a vehicle at a location other than the vehicle manufacturer's specified lift point may cause damage to the vehicle chassis and other components.

4. Look under the vehicle and be sure the floor jack lift pad is contacting the specified lift point. If necessary, lower the lift pad and move it so it contacts the lift point properly.
5. Pump the floor jack handle until the vehicle is at the desired height. Place safety stands adjusted to the appropriate height under the vehicle manufacturer's lift points. These lift points will be a strong chassis member such as the frame or axle housing.
6. Because the floor jack is on casters, the vehicle and floor jack tend to move slightly as the vehicle is lowered onto safety stands. Slowly operate the hydraulic pressure release on the floor jack to lower the vehicle onto the safety stands. As the vehicle is lowered, be sure the safety stands do not tip. All four legs on both safety stands must remain in contact with the floor surface. Be sure the safety stands are contacting the vehicle lift points properly, and double-check to be sure the safety stand legs are all contacting the floor.

WARNING: Never work under a vehicle unless it is securely supported on safety stands. If a vehicle is supported only by a floor jack, the jack may allow the vehicle to drop, resulting in personal injury.

7. After the vehicle is supported properly on safety stands, lower and remove the floor jack to allow more room for under-car service.

WARNING: Never under any condition leave a floor jack handle down so it is near the floor surface; someone may trip over the handle, resulting in personal injury.

Using a Vehicle Lift

A vehicle lift raises a vehicle to allow a technician to perform under-car repairs.

Follow this procedure to raise a vehicle on a lift:

1. Determine both the weight rating of the lift and the vehicle weight to be lifted. Be sure the weight rating of the lift exceeds the vehicle's weight.
2. Before driving a vehicle on a lift, be sure the lift arms are positioned properly out of the path of the vehicle. The lift arms must also be positioned to provide unobstructed clearance between the lift and the vehicle chassis.
3. After driving the vehicle on the lift, be sure the vehicle is properly positioned in relation to the lift. Make sure the vehicle doors, hood, and trunk lid are closed. Do not raise a vehicle with any person inside the vehicle.
4. Determine the specified vehicle lift points from the vehicle service manual (Figure 2-41).
5. Position the lift supports so they are directly under the specified vehicle lift points. Operate the lift so the lift supports contact the specified lift points.

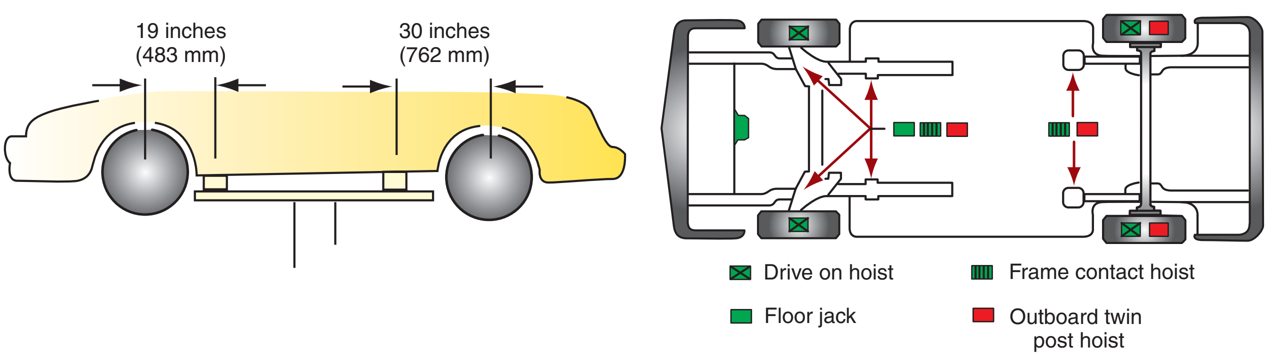


FIGURE 2-41 **Lift points for a typical unibody vehicle.**

WARNING: If the lift supports are not in proper contact with the specified vehicle lift points, the vehicle may slip off the lift, resulting in personal injury and vehicle damage.

6. Operate the lift a short distance off the shop floor and stop the lift. Look under the vehicle to be sure the lift supports are in full contact with the specified lift points. If the lift supports are not in full contact with the specified lift points, lower the vehicle onto the floor and reposition the lift supports.
7. Raise the vehicle to the desired height. Be sure the lift safety mechanism is engaged.

WARNING: If heavy components are removed from one end of a vehicle, the vehicle may become unstable on the lift. Therefore, to prevent this action, chain a strong chassis component to the lift on the opposite end of the vehicle before removing heavy components from the other end.

8. Before lowering the lift, remove all tools, toolboxes, and equipment from under the vehicle, and sweep up discarded parts from under the vehicle.
9. Be sure nobody is standing under the vehicle before lowering it.
10. Lower the vehicle slowly until it is resting on the shop floor and be sure the lift is completely lowered.
11. Before driving the vehicle off the lift, be sure there is proper clearance between all parts of the lift and the vehicle chassis.

CAUTION: When driving a vehicle on a lift, do not run over lift arms, adapters, or axle supports. This action may damage the lift, tires, or vehicle chassis components.

CAUTION: If the lift supports are not in proper contact with the specified vehicle lift points, chassis components such as brake lines may be damaged.

Suspension and Steering Service, Diagnostic, and Measurement Tools

Using a Power Steering Pressure Gauge

The power steering pump pressure test is one of the most important indications of power steering pump condition.

A **power steering pressure gauge** is connected in the power steering system to test power steering pump pressure.

Follow these steps to use the power steering pressure gauge to test power steering pump pressure:

1. Check the power steering belt condition and if it is cracked, damaged, or oil soaked, replace the belt. If a V-belt is bottomed in the pulley, excessive wear on the sides of a V-belt is indicated. This condition also requires belt replacement.
2. Measure the power steering belt tension with a belt tension gauge. If this tension is less than specified, adjust the power steering belt tension.
3. Be sure the engine is warmed up and the power steering fluid is at normal operating temperature.
4. With the engine shut off, check the fluid level in the power steering pump reservoir. If necessary, add the vehicle manufacturer's specified fluid until the proper level is obtained.
5. Listen to the power steering pump with the engine idling. A growling noise from the pump may indicate aeration of the power steering fluid in the reservoir or air in the power steering system. If air is indicated in the system, turn the steering wheel several times fully in each direction to bleed air from the system before proceeding with the power steering pump pressure test.
6. Shut the engine off and remove the high-pressure hose from the power steering pump. Connect the power steering pressure gauge and valve assembly to the fitting on the end of the high-pressure hose and to the fitting on the pump from which the high-pressure

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FIGURE 2-42 **Pressure gauge connections to power steering.**

hose was removed (Figure 2-42). Be sure the valve on the power steering pressure gauge is fully open.

7. With the engine idling, close the power steering gauge valve for no more than 10 seconds and observe the power steering pump pressure on the gauge. Turn the gauge valve fully open. If the power steering pump pressure is less than the vehicle manufacturer's specified pressure, replace the power steering pump.

WARNING: Wear a face shield and protective gloves during the power steering pressure test. Power steering fluid and components become hot during this test.

CAUTION:
Do not allow the power steering fluid to become too hot during the pump pressure test. Excessive fluid temperature reduces pump pressure, resulting in false test results.

WARNING: If the gauge valve is closed for more than 10 seconds during the power steering pressure test, excessive power steering pump pressure may rupture power steering hoses. Hot fluid spraying from a ruptured hose may burn anyone near the vehicle.

8. Shut the engine off and remove the power steering pressure gauge. Tighten the high-pressure hose fitting to the specified torque. Start the engine and check for leaks at this fitting. Be sure the power steering reservoir is filled to the proper level.

Using a Dial Indicator

A dial indicator performs precision measurements on some suspension components such as ball joints. A special dial indicator with a stiff, flexible attaching bracket is available for measuring ball joint wear. When measuring ball joint wear, the end of this flexible bracket is clamped to a stable suspension component with a pair of vise grips. The dial indicator must be mounted so there is no movement in the indicator mounting. A dial indicator contains a movable plunger that is positioned against the component to be measured. The pointer on the dial indicator registers the amount of plunger movement. Each rotation of the pointer represents 0.100 in. (2.54 mm) of plunger movement (Figure 2-43). The dial indicator plunger must be positioned against the component to be measured so the dial indicator is preloaded approximately 0.250 in. (6.35 mm). When the dial indicator is preloaded properly, about

FIGURE 2-43 **The dial indicator pointer rotation indicates the amount of plunger movement.**

one-half of the plunger should be outside the dial indicator. After the preload procedure is completed, the dial indicator face must be rotated until the zero position on the scale is aligned with the pointer. Always look squarely at the indicator face. Looking at the dial indicator face from an angle may provide an inaccurate reading.

The following is a typical procedure for measuring ball joint wear on a short-and-long arm suspension system with the coil spring positioned between the lower control arm and the chassis:

1. Lift the front of the vehicle with a floor jack positioned under the manufacturer's specified lift point, and position a safety stand under the lower control arm. Lower the vehicle so the lower control arm and vehicle weight rests on the safety stand. The tire must remain several inches off the floor.
2. Clamp the end of the dial indicator's flexible bracket onto the lower control arm.
3. Position the dial indicator plunger against the lower side of the steering knuckle next to the nut on the ball joint stud. The dial indicator plunger should be positioned at a 90° angle with the ball joint stud (Figure 2-44).
4. Preload and zero the dial indicator. Be sure the dial indicator is clamped securely to the lower control arm without any movement in the indicator mounting.
5. Position a long steel bar under the tire, and lift upward on the bar while an assistant observes the movement on the dial indicator pointer. If the dial indicator pointer movement exceeds the maximum-specified ball joint vertical movement, the ball joint must be replaced.

FIGURE 2-44 **Dial indicator installed to measure vertical ball joint movement.**

FIGURE 2-45 **Dial indicator installed to measure horizontal joint movement.**

6. Be sure the front wheel bearings are adjusted properly. Position the dial indicator plunger against the inner edge of the wheel rim (Figure 2-45). Preload and zero the dial indicator. Grasp the top and bottom of the tire, and attempt to tip the tire out at the bottom and in at the top. Release the tire, and repeat this procedure several times while an assistant observes the dial indicator. If the dial indicator pointer movement exceeds the maximum-specified ball joint horizontal movement, the ball joint must be replaced.

SERVICE TIP: The procedure for measuring ball joint wear varies depending on the type of suspension system and the type of ball joint mounting. Always consult the vehicle manufacturer's service manual.

Using a Coil Spring Compressing Tool

A coil spring compressing tool is required to compress the coil spring before removing the spring from the strut on a MacPherson strut suspension system.

Follow this procedure for using a coil spring compressing tool to remove a spring from a strut:

1. With the strut-and-coil-spring assembly removed from the vehicle, install the coil spring in the compressing tool according to the tool manufacturer's or vehicle manufacturer's recommended procedure.

CAUTION: If the coil spring has an enamel-type coating, tape the spring in the areas where the compressor tool contacts the spring. If the compressor tool chips this coating, the spring may break prematurely.

WARNING: Unless the coil spring is compressed, never loosen the nut on the strut rod that retains the upper strut mount on the strut and coil spring. Loosening this nut will suddenly release the coil spring tension, resulting in personal injury.

2. Adjust the compressing arms on the spring compressing tool so the arms contact the coils farthest away from the center of the spring (Figure 2-46).

WARNING: Always use the coil spring compressor tool recommended by the vehicle manufacturer. Some compressor tools are designed to work only on specific strut-and-coil-spring assemblies. If the compressor tool does not fit properly on the coil spring, the tool may slip off the spring, suddenly releasing the coil spring tension, which may result in personal injury.

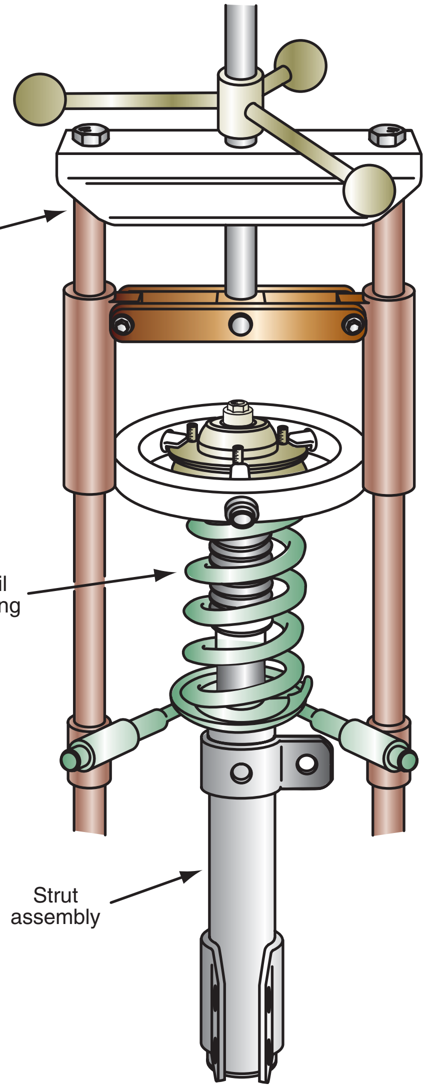

FIGURE 2-46 **Coil spring and strut assembly mounted in a spring compressing tool.**

3. Turn the handle on top of the compressor tool until all the spring tension is removed from the upper strut mount.
4. Loosen and remove the strut rod nut in the center of the upper strut mount (Figure 2-47). Be sure all the spring tension is removed from the upper strut mount before loosening this nut.
5. Remove the upper strut mount assembly, mount bearing, and then remove the upper spring seat and insulator.
6. Rotate the handle on the spring compressing tool to release all the tension on the coil spring, and then remove the spring.
7. Remove the dust shield and jounce bumper from the strut rod, and then remove the lower spring insulator (Figure 2-48).
8. Replace all worn or defective parts, and be sure the strut rod is fully extended. Install the lower insulator on the lower strut spring seat, and be sure the insulator is properly positioned on the seat.
9. Install the spring bumper on the strut rod.
10. Place the coil spring properly in the spring compressing tool, and rotate the handle on the spring compressing tool to compress the coil spring.

CAUTION:
Never clamp the lower end of the strut in a vise, which may cause internal strut damage.

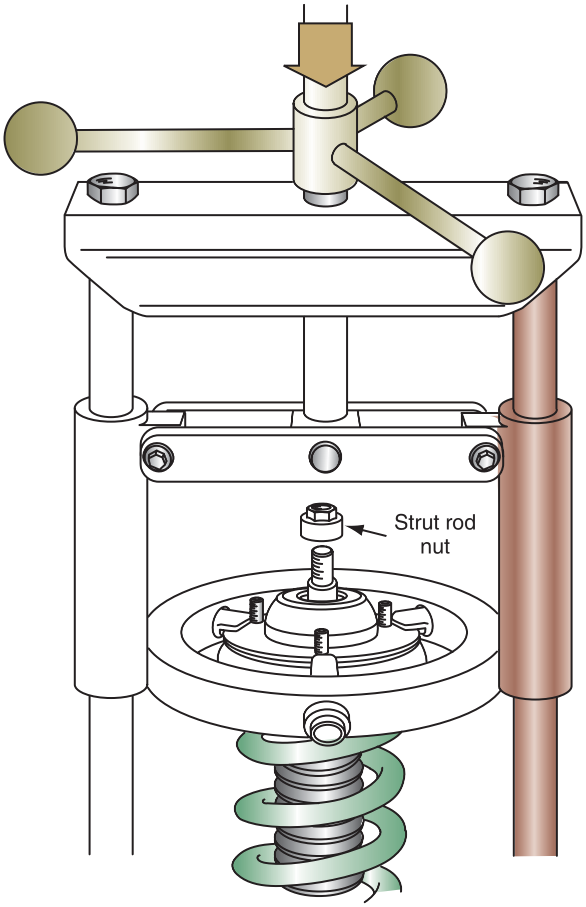

FIGURE 2-47 **After the compressing tool is operated to removed all the spring tension, remove the strut rod nut.**

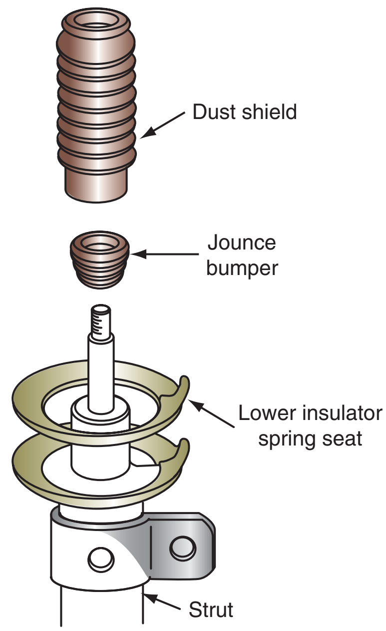

FIGURE 2-48 **Removal of the dust shield, jounce bumper, and lower spring insulator.**

SERVICE TIP: The tire dismounting and mounting procedure varies depending on the type of tire changer. Always follow the dismounting and mounting procedure recommended by the tire changer manufacturer.

CAUTION: Always use the tire changer attachments recommended by the tire changer manufacturer. For example, specific bead removal and installation attachments may be recommended for certain types of wheel rims.

11. Install the strut into the coil spring, and be sure the lower insulator is properly positioned on the coil spring.
12. Install the upper spring insulator and upper strut mount, and be sure these components are properly positioned.
13. Install the strut rod nut and tighten this nut to the specified torque.
14. Rotate the handle on the spring compressing tool to slowly release all the spring tension, and remove the strut and spring assembly from the tool.

Using a Tire Changer

A tire changer dismounts and mounts tires on wheel rims without damaging the rims. Most tire changers are operated by shop air pressure.

WARNING: If the tire changer manufacturer's recommended procedure for dismounting and mounting tires is not followed, personal injury and/or rim damage may occur.

The following is a typical tire dismounting and mounting procedure:

1. Position the tire-and-wheel assembly in the specified location on the tire changer (Figure 2-49). Be sure the tire-and-wheel assembly is properly positioned and secured.
2. Remove the valve cap and valve core, and be sure the tire is completely deflated.
3. Position the bead unseating tool to unseat the outer bead, and operate the changer to unseat this bead.

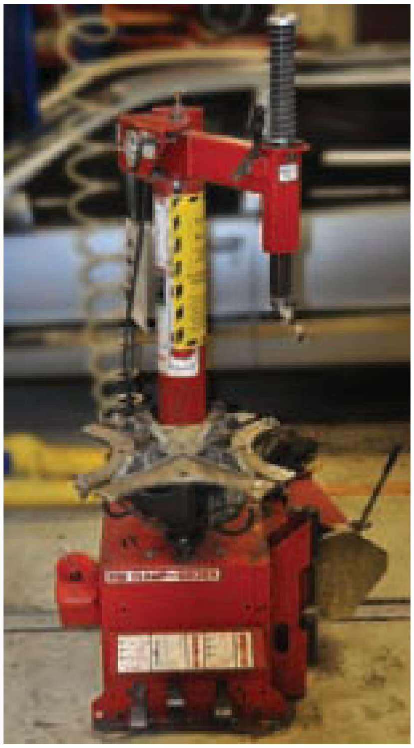

FIGURE 2-49 **Typical tire changer.**

4. Operate the changer to unseat the bead on the inner side of the rim.
5. Position the bead removal tool to remove the outer bead over the rim, and operate the changer to remove this bead over the rim.
6. Position the bead removal tool to remove the inner bead over the rim, and operate the changer to remove this bead over the rim.
7. After the beads are removed over the rim, remove the tire from the changer.
8. Clean dirt and rust from the rim sealing flanges with a wire brush, and apply a coating of rubber compound to the bead area of the tire.
9. Install the tire on top of the rim in the desired position. Many tires have a dot painted on the tire that should be aligned with the valve stem when the tire is mounted on the rim. Therefore, this dot must be on the outer side of the tire prior to mounting.
10. Position the bead installation tool to install the inner bead over the rim, and operate the changer to install this bead over the rim.
11. Position the bead installation tool to install the outer bead over the rim, and operate the changer to install this bead over the rim.
12. Rotate the tire on the rim to align the painted dot with the valve stem, and install the valve core. Be sure the tire is centered properly on the rim.
13. Inflate the tire to the specified tire pressure, install the valve cap, and remove the tire and wheel from the tire changer.

Using a Scan Tool

A **scan tool** performs an electronic diagnosis of computer-controlled suspension systems and other electronic systems. Various test modules may be plugged into the scan tool, depending on the vehicle and system being diagnosed (Figure 2-50). The scan tool cable is connected to the data link connector (DLC) under the dash. On 1996 and newer vehicles with on-board diagnostic II (OBD II) systems, the scan tool is powered from a terminal in the DLC. On most

SERVICE TIP: Many shops have a policy of always installing a new valve stem when repairing or replacing a tire, which prevents problems with cracked or defective valve stems.

SERVICE TIP: Aligning the painted dot on the tire sidewall ensures proper tire balancing with a minimum amount of balance weight.

SERVICE TIP: The valve core may be left out of the valve stem and the tire partially inflated. This action allows the air pressure to enter the tire quicker and seat the beads against the rim flanges. After the beads are seated, allow most of the air to escape from the tire, and then install the valve core.

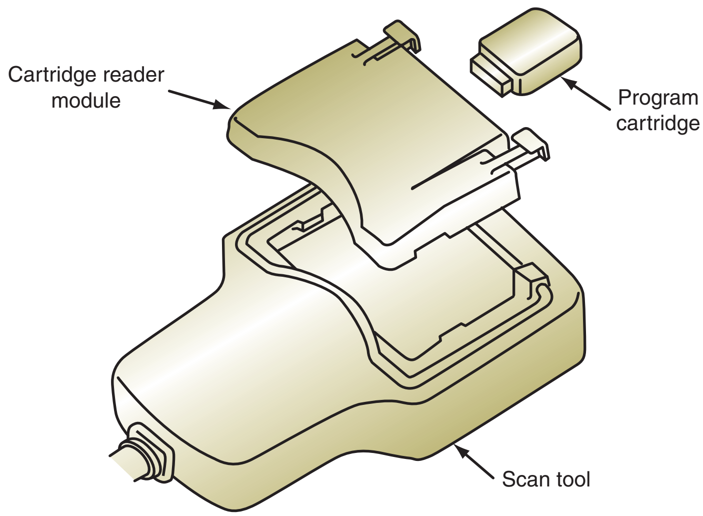

FIGURE 2-50 **Scan tool and related modules.**

CAUTION:
Never connect or disconnect the scan tool data cable with the ignition switch on. This action may damage expensive electronic components on the vehicle or the scan tool.

pre-1996 vehicles, a power cable on the scan tool has to be connected to a 12V power source such as the cigarette lighter.

After the scan tool is connected, the vehicle make, model year, and engine size usually has to be selected on the scan tool display. On vehicles with several different computer systems, the technician must select the computer system to be diagnosed from the list of computer systems on the vehicle. For example, if the technician wants to diagnose the continuously variable road sensing suspension system (CVRSS), then RSS must be selected from the list of computer systems displayed on the scan tool display. After the RSS selection, the scan tool display will ask the technician to select diagnostic trouble codes (DTCs), data, inputs, outputs, or clear codes.

On OBD II vehicles, the DTCs contain five digits. A typical DTC from a CVRSS is C1712. The "C" indicates this DTC is in the chassis group, and the "1" informs the technician this is a manufacturer specific code. A common DTC dictated by Society of Automotive Engineers (SAE) standards is indicated if the second digit is a "0." The digits 712 in the DTC indicate an open circuit in the left front (LF) damper actuator circuit. On a CVRSS, the damper actuators are solenoids in each shock absorber or strut. Diagnostic trouble codes (DTCs) indicate a defect in a certain electrical area, but they do not indicate a defect in a specific component. For example, the C1712 DTC indicates there is an open circuit in the LF damper actuator solenoid or in the connecting wires between this solenoid and the suspension computer. The technician usually has to use a volt-ohm meter to locate the exact cause of the DTC. Diagnostic trouble codes (DTCs) may be identified on the scan tool display as CURRENT or HISTORY. A CURRENT DTC is one that is pres ent at the time of testing. A HISTORY DTC represents an intermittent defect that occurred in the past, which has since disappeared.

If "data" is selected, the scan tool display indicates data related to the CVRSS. This data includes readings from the input sensors and readings such as battery voltage or vehicle speed. When "inputs" is selected, the scan tool displays readings from the input sensors in the CVRSS. In the "output" parameter the scan tool displays readings from the outputs in the CVRSS. The output displays may be a voltage reading or solenoids displayed as being "on" or "off." If "clear codes" is selected on the scan tool display, the DTCs are erased from the computer memory.

Depending on the computer-controlled suspension system being diagnosed, the scan tool may be used to perform different functions. For example, on some computer-controlled air suspension systems, the scan tool may be used to command the suspension computer to fill and vent each air spring. This test mode may be used to check the operation of system components. The scan tool may be used to flash program the suspension computer memory. This mode installs new software in the computer as directed by service bulletins from the original

equipment manufacturer (OEM). On some computer-controlled suspension systems, such as the system on the 2002 Lincoln Blackwood, the scan tool is used to adjust the suspension ride height.

Using an Electronic Wheel Balancer

The most popular type of wheel balancer in automotive service shops is the electronic balancer. Most electronic wheel balancers have an electric motor that spins the tire-and-wheel assembly at moderate speed during the balance procedure. On some electronic wheel balancers, the tire-and-wheel assembly is spun by hand for balance purposes. Certain preliminary checks must be performed on the tire-and-wheel assembly before installing this assembly on an electronic wheel balancer.

These preliminary checks include the following:

1. Clean all mud and debris from the tire-and-wheel assembly.
2. Remove all old wheel weights from the rim.

WARNING: Improperly installed wheel weights may fly off the rim when the wheel is spun on the balancer, resulting in personal injury.

3. Remove objects such as stones from the tire tread.

WARNING: Stones or other objects in the tire tread may fly out when the wheel is spun on the balancer, resulting in personal injury.

4. Inspect the tire tread and sidewall for defects, such as splits, cuts, chunks out of the tread or sidewall, and bulges indicating ply separation. Replace tires with these defects.
5. Inflate the tire to the specified pressure.

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The tire-and-wheel assembly must be installed on the wheel balancer according to the instructions of the wheel balancer manufacturer. After the tire-and-wheel assembly is installed securely on the balancer, slowly rotate the tire by hand and listen for objects such as balls of rubber rolling inside the tire. Objects inside the tire must be removed, because they make wheel balancing difficult or impossible.

WARNING: If the tire-and-wheel assembly is not securely installed on the wheel balancer, the wheel may come loose and fly off the balancer during the balance procedure, resulting in personal injury.

Use a dial indicator to measure vertical and lateral tire and wheel runout. If tire and wheel runout is excessive, wheel balancing may be difficult. Enter the wheel diameter, width, and offset in the wheel balancer. The balancer must have this information to calculate the required amount of wheel weight and the weight position. Lower the safety hood on the wheel balancer, and activate the balancer to spin the wheel. Apply the brake on the balancer to stop the wheel. Install the indicated amount of wheel weight in the proper position as indicated on the wheel balancer display. Be sure the weight(s) are securely attached to the wheel rim.

Using a Computer Four Wheel Aligner

If a vehicle has a frame and a live-axle rear suspension system, it is not as likely to require rear wheel alignment as a unibody vehicle with a semi-independent or independent rear suspension system. Because of increased four wheel alignment requirements on unibody cars, most

A **computer four wheel aligner** uses a wheel sensor mounted on each wheel to measure all the front and rear wheel alignment angles.

shops that offer wheel alignment service are equipped with a computer four wheel aligner. Before performing a wheel alignment, the technician must complete a preliminary vehicle inspection. The purpose of the preliminary inspection is to locate any defective or worn components that would make wheel alignment inaccurate.

A preliminary wheel alignment inspection includes these checks:

1. Be sure the vehicle has the normal curb weight that it has when the driver is operating the vehicle. Make sure the gas tank is full, and check for excessive mud adhered to the underside of the chassis.
2. Be sure the tires are inflated to the specified tire pressure, and inspect the tires for excessive wear, bulges, cuts, and splits. Be sure the tires are all the same size.
3. Check for the specified front and rear suspension height. Because the suspension height affects many of the wheel alignment angles, this height must be corrected before performing a wheel alignment if it is not within specifications.
4. Check the steering wheel free play. If this free play is more than specified, inspect the steering linkages and tie rod ends for excessive wear. The excessive steering wheel free play must be corrected before a wheel alignment, because this problem affects front wheel toe and steering quality.
5. Be sure the shock absorbers and struts are in satisfactory condition.
6. Check the front and rear wheel bearing adjustments, and correct these adjustments as necessary. Loose wheel bearing adjustments affect some of the wheel alignment angles.
7. Check the ball joints for excessive wear. Worn ball joints affect some of the wheel alignment angles.
8. Inspect the front and rear, upper and lower control arms for damage, and inspect all the control arm bushings for wear. Bent control arms or worn control arm bushings affect wheel alignment angles.
9. Inspect the front and rear stabilizer bars and bushings. Worn stabilizer bushings affect ride quality and vehicle handling.

After the preliminary inspection is completed, and all the necessary components have been replaced or adjusted, drive the vehicle onto the wheel alignment rack.

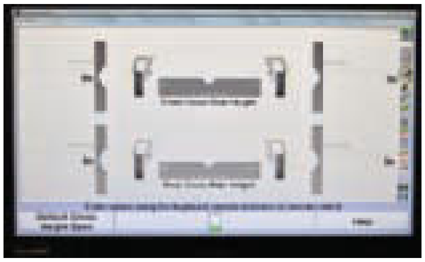
Then follow this procedure to complete the four wheel alignment with a computer wheel aligner:

1. Follow all instructions provided in the wheel aligner operator's manual.
2. Be sure the front wheels are centered on the wheel aligner turntables.
3. Be sure the rear wheels are positioned properly on the slip plates.
4. Mount the wheel sensor units on each wheel.
5. Select the vehicle make and model year on the wheel aligner screen.
6. On the wheel aligner preliminary inspection screen, check the condition of each item. Most of these items are mentioned in the previous preliminary inspection procedure.
7. Display the ride height screen on the wheel aligner, and be sure the front and rear ride height is within specifications.
8. Display the wheel runout screen of the wheel aligner, and compensate for wheel runout as directed.
9. Display the turning angle screen on the wheel aligner. Apply the brakes with a brake pedal depressor as directed on the screen, and perform the turning angle check.
10. Display the front and rear wheel alignment angles on the screen. Most computer four wheel aligners mark the alignment angles that are not within specifications.
11. Display the adjustment screen on the wheel aligner, and perform the necessary front and rear suspension adjustments to bring all the alignment angles within specifications. Photo Sequence 2 illustrates a typical procedure for performing a four wheel alignment with a computer wheel aligner.

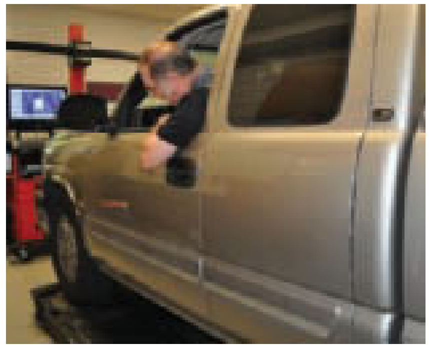
SERVICE TIP: The wheel runout compensation procedure varies, depending on the make and year of the wheel aligner.

PHOTO SEQUENCE 2

Typical Procedure for Performing Four Wheel Alignment with a Computer Wheel Aligner



P2-1 **Display the ride height screen. Check the tire condition for each tire on the tire condition screen.**

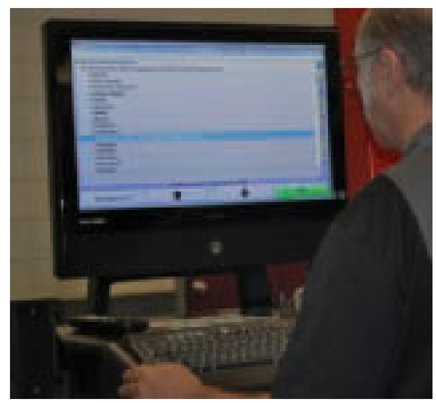


P2-2 **Position the vehicle on the alignment rack.**

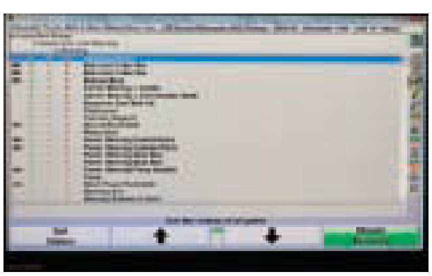
P2-3 **Make sure the front tires are positioned properly on the turntables.**

P2-4 **Position the rear wheels on the slip plates.**

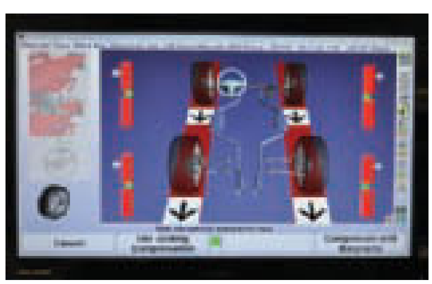
P2-5 Attach the wheel units.



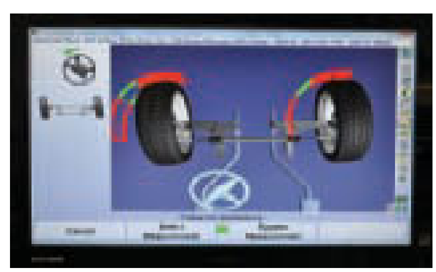
P2-6 **Select the vehicle make and model year.**



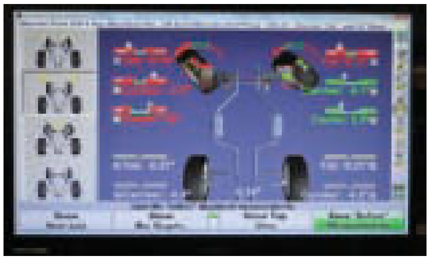
P2-7 **Check the items on the screen during the preliminary inspection.**



P2-8 **Display the wheel runout compensation screen.**



P2-9 **Display the turning angle screen and perform the turning angle check.**



P2-10 **Display the front and rear wheel alignment angle screen.**

P2-11 **Display the adjustment screen.**

Employer and Employee Obligations

The ever increasing electronics content on today's vehicles also requires that technicians are familiar with the latest electronics technology. To be a successful automotive technician, you must be committed to lifelong training. There are many different ways to obtain this training, but it is absolutely essential.

Automotive training may be obtained by these methods:

1. Obtain bulletins, service manuals, and training information from original equipment manufacturers (OEMs); independent parts and component manufacturers; and independent suppliers of service manuals and training books. After the information is obtained, it is essential that you read and study it.
2. Join an organization dedicated to supplying information to automotive service technicians such as the International Automotive Technician's Association (IATA).
3. Join an Internet organization such as the International Automotive Technicians Network where you can communicate with other technicians and obtain answers to service problems.
4. Download information available on the Internet from automotive equipment manufacturers. Many of these manufacturers provide operator's manuals and other information on their equipment for downloading purposes.
5. Attend satellite training seminars available from some independent automotive training organizations and OEMs.
6. Attend training seminars in your location sponsored by equipment and parts manufacturers or OEMs.
7. Attend training seminars sponsored by the automotive department at your local college.
8. Attend National Institute for Automotive Service Excellence (ASE) certification classes.

Successful automotive technicians must be committed to lifelong training, but their employers must also be committed to assisting them in obtaining the necessary training. This assistance may be financial, providing time off work to attend training seminars or arranging the necessary training programs.

When you begin employment, you enter into a business agreement with your employer. A business agreement involves an exchange of goods or services that have value. Although the automotive technician may not have a written agreement with his or her employer, the technician exchanges time, skills, and effort for money paid by the employer. Both the employee and the employer have obligations.

The automotive technician's obligations include the following:

1. Productivity: As an automotive technician you have a responsibility to your employer to make the best possible use of time on the job. Each job should be done in a reasonable length of time. Employees are paid for their skills, effort, and time.

2. Quality: Each repair job should be a quality job! Work should never be done in a careless manner. Nothing improves customer relations like quality workmanship.
3. Teamwork: The shop staff are a team, and everyone including technicians and management personnel is a team member. You should cooperate with and care about other team members. Each member of the team should strive for harmonious relations with fellow workers. Cooperative teamwork helps improve shop efficiency, productivity, and customer relations. Customers may be "turned off" by bickering between shop personnel.
4. Honesty: Employers and customers expect and deserve honesty from automotive technicians. Honesty creates a feeling of trust among technicians, employers, and customers.
5. Loyalty: As an employee, you are obliged to act in the best interests of your employer, both on and off the job.
6. Attitude: Employees should maintain a positive attitude at all times. As in other professions, automotive technicians have days when it may be difficult to maintain a positive attitude. For example, there will be days when the technical problems on a certain vehicle are difficult to solve. However, a negative attitude certainly will not help the situation! A positive attitude has a positive effect on the job situation as well as on the customer and employer.
7. Responsibility: You are responsible for your conduct on the job and your work-related obligations. These obligations include always maintaining good workmanship and customer relations. Attention to details such as always placing fender, seat, and floor mat covers on customer vehicles prior to driving or working on the vehicle greatly improve customer relations.
8. Following directions: All of us like to do things "our way." Such action, however, may not be in the best interests of the shop; as an employee, you have an obligation to follow the supervisor's directions.
9. Punctuality and regular attendance: Employees have an obligation to be on time for work and to be regular in attendance on the job. It is very difficult for a business to operate successfully if it cannot count on its employees to be on the job at the appointed time.
10. Regulations: Automotive technicians should be familiar with all state and federal regulations pertaining to their job situation, such as the Occupational Safety and Health Act (OSHA) and hazardous waste disposal laws. In Canada, employees should be familiar with workplace hazardous materials information systems (WHMIS).

Employer to employee obligations include:

1. Wages: The employer has a responsibility to inform the employee regarding the exact amount of financial remuneration they will receive and when they will be paid.
2. Fringe benefits: A detailed description of all fringe benefits should be provided by the employer. These benefits may include holiday pay, pension plans, and sickness and accident insurance.
3. Working conditions: A clean, safe workplace must be provided by the employer. The shop must have adequate safety equipment and first-aid supplies. Employers must be certain that all shop personnel maintain the shop area and equipment to provide adequate safety and a healthy workplace atmosphere.
4. Employee instruction: Employers must provide employees with clear job descriptions and be sure that each worker is aware of his or her obligations.
5. Employee supervision: Employers should inform their workers regarding the responsibilities of their immediate supervisors and other management personnel.
6. Employee training: Employers must make sure that each employee is familiar with the safe operation of all the equipment that they are required to use in their job situation. Since automotive technology is changing rapidly, employers should provide regular update training for their technicians. Under the Right-to-Know Laws, employers are required to inform all employees about hazardous materials in the shop. Employees should be familiar with material safety data sheets (MSDSs), which detail the labeling and handling of hazardous waste, and the health problems if exposed to hazardous waste.

Job Responsibilities

An automotive technician has specific responsibilities regarding each job performed on a customer's vehicle.

These job responsibilities include:

1. Do every job to the best of your ability. There is no place in the automotive service industry for careless workmanship! Automotive technicians and students must realize they have a very responsible job.
2. Treat customers fairly and honestly on every repair job. Do not install parts that are unnecessary to complete the repair job.
3. Use published specifications; do not guess at adjustments.
4. Follow the service procedures in the service manual provided by the vehicle manufacturer or an independent manual publisher.
5. When the repair job is completed, always be sure the customer's complaint has been corrected.
6. Do not be too concerned with work speed when you begin working as an automotive technician. Speed comes with experience.

Liable Responsibilities

During many repair jobs you, as a student or technician working on a customer's vehicle, actually have the customer's life and the vehicle safety in your hands. For example, if you are doing a brake job and leave the nuts loose on one wheel, that wheel may fall off the vehicle at high speed. This could result in serious personal injury for the customer and others, plus extensive vehicle damage. If this type of disaster occurs, the individual who worked on the vehicle and the shop may be involved in a very expensive legal action. As a student or technician working on customer vehicles, you are responsible for the safety of every vehicle that you work on! Even when careless work does not create a safety hazard, it leads to dissatisfied customers, who often take their business to another shop. Nobody benefits when that happens.

National Institute for Automotive Service Excellence (ASE) Certification

The National Institute for Automotive Service Excellence (ASE) has provided voluntary testing and certification of automotive technicians on a national basis for many years. The image of the automotive service industry has been enhanced by the ASE certification program. More than 415,000 technicians now have current certifications and work in a wide variety of automotive service shops.

ASE provides certification in eight areas of automotive repair:

1. Engine repair
2. Automatic transmissions/transaxles
3. Manual drivetrain and axles
4. Suspension and steering
5. Brakes
6. Electrical systems
7. Heating and air conditioning
8. Engine performance

A technician may take the ASE test and become certified in any or all of the eight areas. When a technician passes an ASE test in one of the eight areas, an Automotive Technician's shoulder patch is issued by ASE. Technicians who pass all eight tests receive a Master Technician's shoulder patch (Figure 2-51). Retesting at five-year intervals is required to

FIGURE 2-51 **ASE certification shoulder patches worn by Automotive Technicians and Master Technicians.**

remain certified. The certification test in each of the eight areas contains 40 to 80 multiple-choice questions. The test questions are written by a panel of automotive service experts from various areas of automotive service, including automotive instructors, service managers, automotive manufacturers' representatives, test equipment representatives, and certified technicians. The test questions are pretested and checked for quality by a national sample of technicians. On an ASE certification test, approximately 45 to 50 percent of the questions are Technician A and Technician B format, and the multiple-choice format is used in 40 to 45 percent of the questions. Less than 10 percent of ASE certification questions are an EXCEPT format in which the technician selects one incorrect answer out of four possible answers. ASE regulations demand that each technician must have two years of working experience in the automotive service industry prior to taking a certification test or tests. However, relevant formal training may be substituted for one year of working experience. Contact ASE for details regarding this substitution. The contents of the suspension and steering test are listed in Table 2-1.

ASE also provides certification tests in automotive specialty areas, such as Parts Specialist; Advanced Engine Performance Specialist; Alternate Fuels, Light Vehicle—Compressed Natural Gas; Machinist, Cylinder Head Specialist; Machinist, Cylinder Block Specialist; and Machinist, Assembly Specialist.

Shops that employ ASE-certified technicians display an official **ASE blue seal of excellence**. This blue seal increases the customer's awareness of both the shop's commitment to quality service and the competency of its certified technicians.

TABLE 2-1 **SUSPENSION AND STEERING TEST SUMMARY**

Content area	Questions in test	Percentage of test
A. Steering systems diagnosis and repair 1. Steering columns and manual steering gears (3) 2. Power-assisted steering units (4) 3. Steering linkage (3)	10	25%
B. Suspension systems diagnosis and repair 1. Front suspensions (6) 2. Rear suspensions (5) 3. Miscellaneous service (2)	13	33%
C. Wheel alignment diagnosis, adjustment, and repair	12	30%
D. Wheel and tire diagnosis and repair	5	12%
TOTAL	**40**	**100%**

Repair Orders (R.O.)

Repair orders may vary depending on the shop, but repair orders usually have this basic information:

1. Customers name, address, and phone number(s)
2. Customer's signature
3. Vehicle make, model, year, and color
4. Vehicle identification number (VIN)
5. Vehicle mileage
6. Engine displacement
7. Date and time
8. Service writers code number
9. Work order number
10. Labor rate
11. Estimate of repair costs
12. Accurate and concise description of the vehicle problem.

In many shops the repair orders are completed on a computer terminal, and the computer may automatically write the vehicle repair history on the repair order if the vehicle has a previous repair history in the shop computer system.

The repair order informs the technician regarding the problem(s) with the vehicle. In many shops the technician has to enter a starting time on the repair order. This may be done on a computer terminal or by inserting the work order into the time clock. The technician may also have to enter his code number on the work order to indicate who worked on the vehicle. The technician's code number on the work order is also used to pay the technician for the repair job. The technician must diagnose and repair the problem(s) indicated on the repair order. When the technician obtains parts from the parts department to complete the repair, the technician must present the order number. The parts personnel enter the parts and the cost on the repair order. In some shops the technician is required to enter an accurate description of the completed repairs on the work order. For example, the description of the problem on the work order may be "A/C system inoperative." If the technician replaced the A/C compressor fuse to correct the problem, he or she may enter, "Diagnosed A/C electrical defects and found a blown A/C fuse. Replaced the fuse and operated the A/C system. A/C system operation is normal." Some shops require the service writer or shop foreman to sign the work order when the repair job is successfully completed. The work order is routed back to the accountant who calculates all the charges on the work order including the appropriate taxes. Some shops add a miscellaneous charge on the work order. A typical miscellaneous charge is 10 percent of the total charges on the work order. This miscellaneous charge is to cover the cost of small items such as bolts, cotter pins, grease, lubricants, and sealers that are not entered separately on the work order.

In many shops the technicians work on a flat rate basis. In these shops the technician is paid a flat rate for each repair. In dealership the flat rate time is set by the vehicle manufacturer. Independent shops use generic flat rate manuals published by firms such as Mitchell Publications. If the flat rate time is 2 hours for completing a specific vehicle repair, the customer is charged for 2 hours, and the technician is paid for 2 hours even though he or she completed the repair in 1.5 hours. Conversely, if the technician takes 2.5 hours to complete the job, the technician is only paid for 2 hours and the customer is charged for 2 hours. The flat rate time is usually entered on the work order.

Service Manuals

The service manual is one of the most important tools for today's technician. It provides information concerning component identification, service procedures, specifications, and diagnostic information. In addition, the service manual provides information concerning

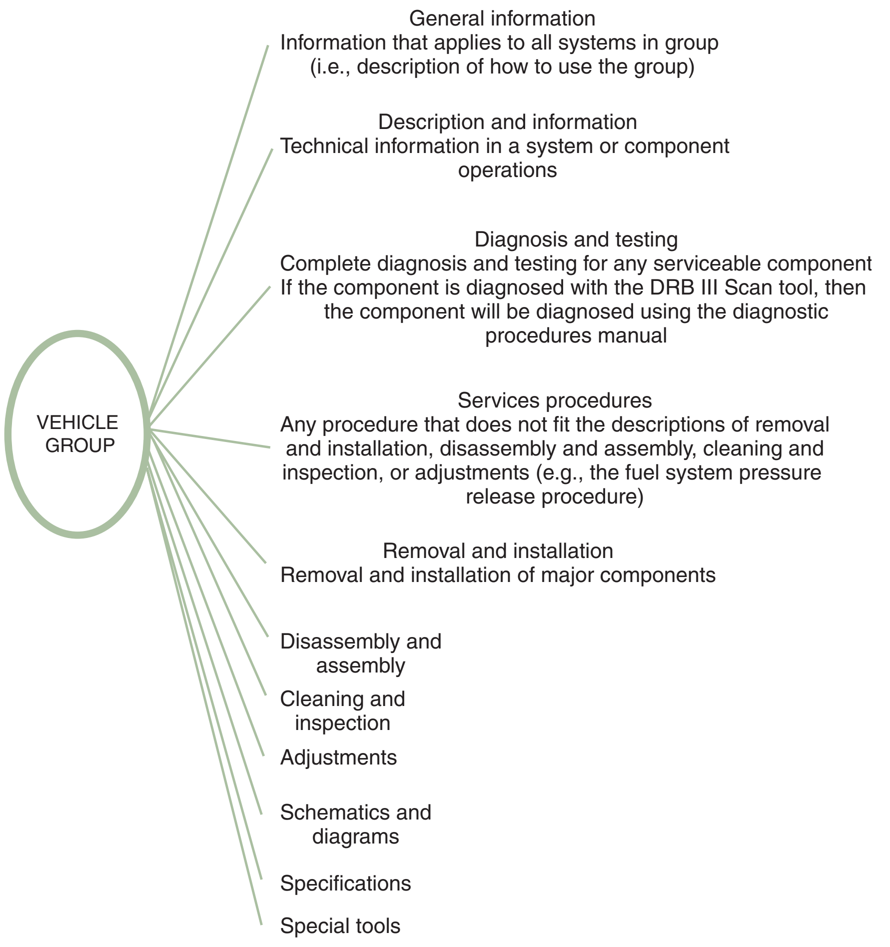


FIGURE 2-52 **Uniform service manual layout.**

wiring harness connections and routing, component location, and fluid capacities. Service manuals can be supplied by the vehicle manufacturer or through aftermarket suppliers.

The service manual provides an explanation of the vehicle identification number (VIN). The VIN information is essential when ordering parts. Most service manuals published by vehicle manufacturers now have a standard format (Figure 2-52). The service manual usually provides illustrations to guide the technician through the service operation (Figure 2-53). Always use the correct manual for the vehicle and system being serviced. Follow each step in the service procedure. Do not skip steps! Measurements such as torque, end play, and clearance specifications are located in or near the service manual text or procedural information. Specification tables are usually provided at the end of the procedural information or component area (Figure 2-54).

Because the service manual is divided into a number of main component and system areas, a table of contents is provided at the front of the manual to provide quick access to the desired information. Each component area or system is covered in a section of the service manual (Figure 2-55). At the beginning of each section in the service manual, a smaller table of contents guides the technician to the information regarding the specific system or component being serviced. The service manual may be divided into several volumes, because of the extensive amount of information required to service today's vehicles. Diagnostic information in each section of the service manual is usually provided in **diagnostic procedure charts** (Figure 2-56). The test results obtained in a specific diagnostic step guide the technician to the next appropriate step.

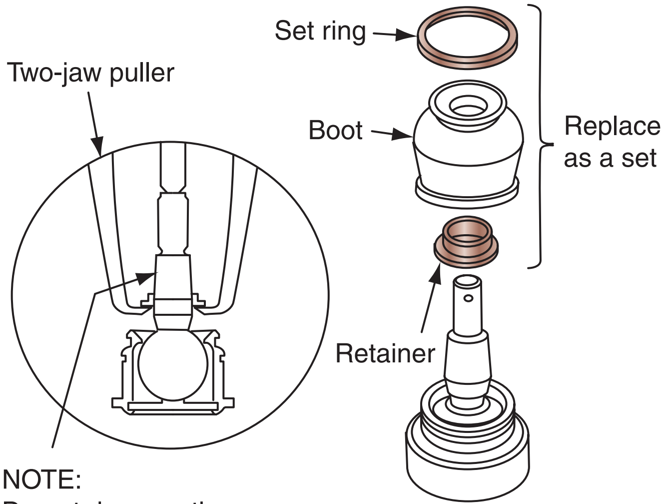
A **diagnostic procedure chart** may be called a diagnostic tree.

Service and parts information can also be provided through computer services (Figure 2-57). Computerized service information may be provided on computer disks or compact disks (CDs), which are easier to store and access. Computers may also be connected to a central

Ball Joint Boot Replacement

NOTE: The upper control arm ball joint, lower control arm ball joint, and knuckle upper ball joint are attached with the boot retainer to improve the sealing efficiency of the boot.

1. Remove the set ring and boot.

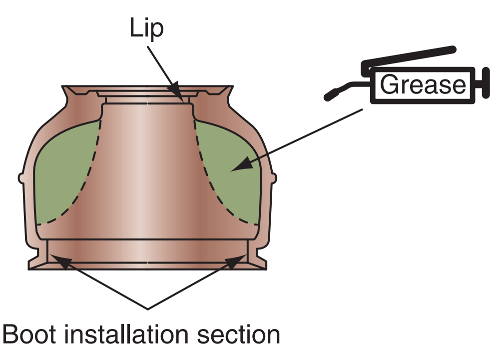


NOTE:
Do not damage the tapered section of the ball pin with the bearing puller.

2. Remove the retainer.

NOTE: The knuckle lower ball joint does not have a retainer.

3. Pack the interior of the boot and lip with grease.

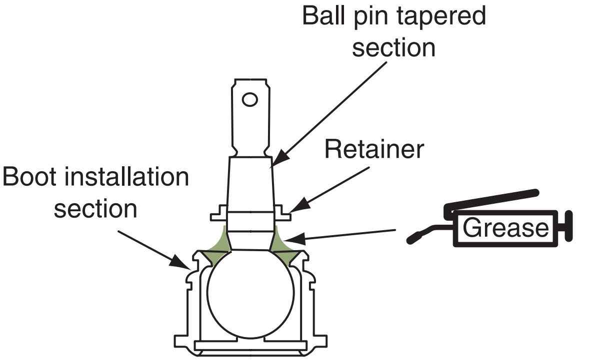


CAUTION: Do not contaminate the boot installation section with grease.

4. Wipe the grease off the sliding surface of the ball pin, and pack with fresh grease.

5. Insert the new retainer lightly into the ball joint pin.

NOTE: When installing the ball joint, press the retainer into the ball joint pin.



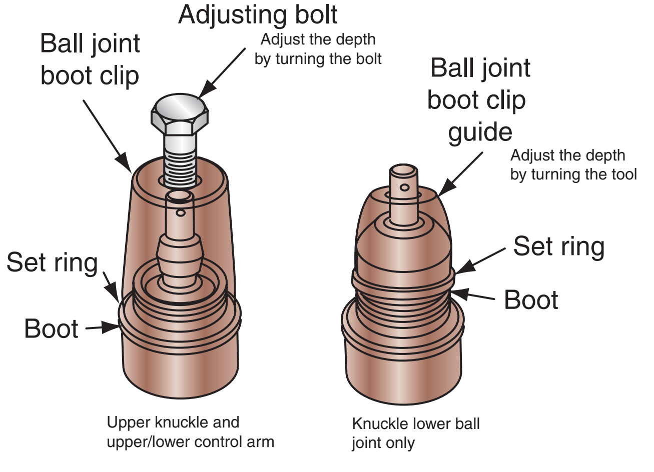
CAUTION:

Keep grease off the boot installation section and the tapered section of the ball pin.

Do not allow dust, dirt, or other foreign materials to enter the boot.

6. Install the boot in the groove of the boot installation section securely, then bleed air.

7. Adjust the special tool with the adjusting bolt until the end of the tool aligns with the groove on the boot.



8. Slide the set ring over the tool and into position.

CAUTION: After installing the boot, check the ball pin tapered section and threads for grease contamination and wipe them if necessary.

FIGURE 2-53 **Illustrations in the service manual that guide the technician through service procedures.**

			Pressure	
		Tire size	Front	Rear
Cold tire inflation pressure	For all roads including full rated loads	P195/70R14	220 kPa (2.2 kgf/cm², 32 psi)	240 kPa (2.4 kgf/cm², 34 psi)
		P205/65R15	220 kPa (2.2 kgf/cm², 32 psi)	240 kPa (2.4 kgf/cm², 34 psi)
	Optional inflation for reduced loads (1 to 4 passengers)	P195/70R14	180 kPa (1.8 kgf/cm², 26 psi)	180 kPa (1.8 kgf/cm², 26 psi)
		P205/65R15	180 kPa (1.8 kgf/cm², 26 psi)	180 kPa (1.8 kgf/cm², 26 psi)
Vehicle height	Tire size		Height	
			Front	Rear
	P195/70R14		210 mm (8.27 in.)	270 mm (10.63 in.)
	P205/65R15		213 mm (8.39 in.)	276 mm (10.87 in.)
Front wheel alignment	Toe-in (total)		0˚ +/- 0.2˚ (0 +/- 2 mm, 0 +/- 0.08 in.)	
	Wheel angle	Tire size	Inside wheel	Outside wheel
		P195/70R14	37˚20' +/- 2˚	32˚15'
		P205/65R15	36˚00' +/- 2˚	31˚20'
	Camber		-0˚35' +/- 45'	
	Cross camber		45' or less	
	Caster		1˚05' +/- 45'	
	Cross caster		45' or less	
	Steering axis inclination		13˚00' +/- 45'	
Rear wheel alignment	Toe-in (total)		0.4˚ +/- 0.2˚ (4 +/- 2 mm, 0.16 +/- 0.08 in.)	
	Camber		-0˚15' +/- 45'	
	Cross camber		45' or less	

FIGURE 2-54 **Specification table.**

database to obtain service information. Using the mouse, light pen, computer keyboard, or touch-sensitive screen, the technician selects choices from a series of menus on the computer monitor. When the desired information is accessed, it may be printed out for detailed study. Modern automotive service information is presently computer or Web-based.

Service procedures may be modified by the vehicle manufacturer at any time. Service bulletins provide up-to-date corrections for the service manuals. If a significant number of corrections are required, a second edition of the manual may be published. When service information is provided on CDs, the CDs are updated frequently to provide the latest information.

CUSTOMER CARE: When advising customers regarding when the work will be completed on their car, it is a good idea to estimate a longer time than you anticipate. For example, if you expect it will take 3 hours to repair the vehicle, advise the customer it will be ready in 4 hours. This allows extra time for diagnosing difficult problems or road testing the vehicle. It can be very frustrating for customers when they come to pick up their vehicle at the appointed time, and the vehicle is not ready.

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FIGURE 2-55 **The table of contents directs you to the major systems and component areas in the service manual.**

EPS INDICATOR LIGHT DOES NOT COME ON

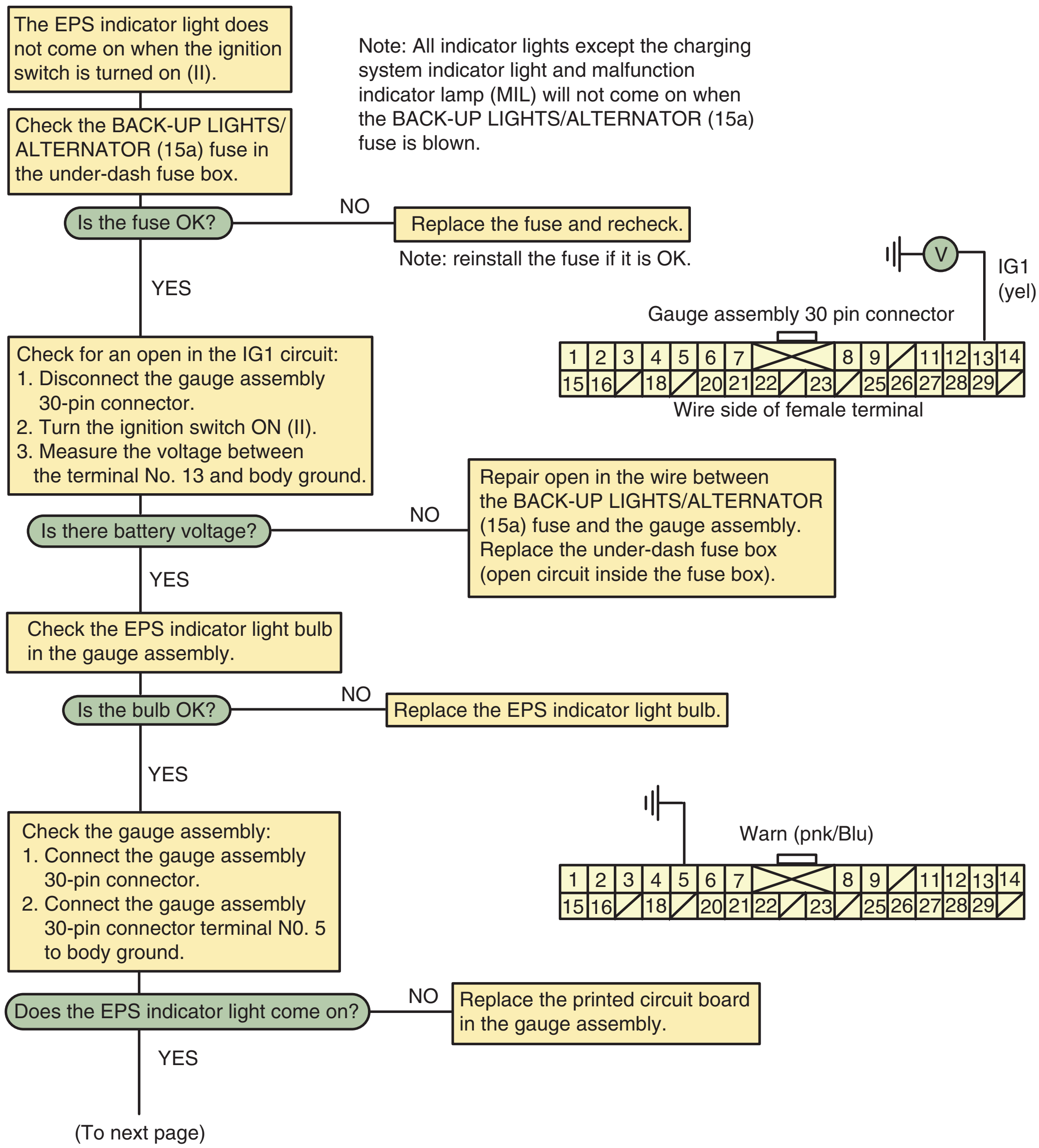


FIGURE 2-56 **Typical diagnostic chart.**

FIGURE 2-57 **Computers are replacing printed service manuals in many shops.**

Terms to Know

ASE blue seal of excellence
Axle puller
Ball joint removal and installation tools
Bearing puller
Brake pedal jack
Coil spring compressing tool
Computer four wheel aligner
Control arm bushing tools
Diagnostic procedure charts
Dial indicator
Electronic wheel balancer
Floor jack
Hydraulic press
International system (SI)
Machinist's rule
Magnetic wheel alignment gauge
Pitman arm puller
Plumb bob
Power steering pressure gauge
Rim clamp
Safety stands
Scan tool
Seal driver
Steering wheel locking tool
Stethoscope
Tie rod sleeve adjusting tool
Tire changer
Tie rod end and ball joint puller
Tire tread depth gauge
Toe gauge
Track gauge
Tram gauge
Turning radius gauge turntables
U.S. customary (USC) system
Vacuum hand pump
Vehicle lift

CASE STUDY

A technician was removing and replacing the alternator of a General Motors car. After installing the replacement alternator and connecting the alternator battery wire, she proceeded to install the alternator belt. The rubber boot was still removed from the alternator battery terminal. While installing this belt, her wristwatch expansion bracelet made electrical contact from the alternator battery terminal to ground on the alternator housing. Even though the alternator battery wire is protected with a fuse link, which melted, a high current flowed through the wristwatch bracelet. This heated the bracelet to a very high temperature and severely burned the technician's arm.

The technician forgot two safety rules:

1. Never wear jewelry, such as watches and rings, while working in an automotive shop.
2. Before performing electrical work on a vehicle, disconnect the negative battery cable. If the vehicle is equipped with an air bag, wait the specified time after this cable is disconnected.

CASE STUDY

A customer brought a Cavalier into the shop with a rough idle complaint. The customer informed the service salesman that he had this problem since the car was purchased new, and the problem was always caused by an open exhaust gas recirculation (EGR) valve. The customer said the (EGR) valve had been replaced three times under warranty, and he had also paid for an EGR valve replacement, and one EGR valve cleaning, after the warranty had expired.

The technician connected a scan tool to the DLC, and verified that a diagnostic trouble code (DTC) was present indicating the EGR valve was stuck open. Next the technician checked for technical service bulletins (TSBs) related to this problem in the shop database. One TSB indicated that the vehicle manufacturer had revised powertrain control module (PCM) software that caused the PCM to pulse the EGR valve briefly each time the PCM closed the EGR valve to remove carbon buildup on the EGR valve pintle. Using the appropriate equipment the technician installed the updated software in the PCM, and this permanently corrected the problem.

Previous technicians who serviced this vehicle had forgotten, or neglected, to check the TSB database for the cause of this problem. As a result, both the vehicle manufacturer and the customer spent a considerable amount of money for EGR valve replacements, when computer reprogramming was required to correct the problem.

CASE STUDY

A technician had just replaced the engine in a Ford vehicle and was performing final adjustments. In this shop, the cars were parked in the work bays at an angle on both sides of the shop. With the engine running at fast idle, the automatic transmission suddenly slipped into reverse. The car went backward across the shop and collided with a car in one of the electrical repair bays. Both vehicles were damaged to a considerable extent. Fortunately, no personnel were injured.

This technician forgot to apply the parking brake while working on the vehicle!

Summary

- Each unit in the metric system of measurements can be multiplied or divided by 10 to obtain larger or smaller units.
- A stethoscope amplifies sound to help the technician identify the source of abnormal noises.
- A dial indicator is a precision measuring device that measures movement or wear on various components in thousands of an inch.
- A tire changer is a pneumatically operated machine that is used to dismount and mount tires on rims.
- An electronic wheel balancer indicates static and dynamic unbalance in tire and wheel assemblies. The electronic wheel balancer also indicates the mounting location and size of wheel weight(s) required to provide a balanced tire and wheel assembly.
- A spring compressor tool compresses a coil spring so the spring and other suspension components can be safely removed.
- A power steering pressure gauge is used to test power steering pump pressure and determine the condition of the power steering system.
- Turning radius gauges are placed under the front wheels during a wheel alignment.
- A magnetic wheel alignment gauge may be attached to the outer surface of the front wheel hubs to measure certain wheel alignment angles.
- A computer four wheel aligner is used to electronically measure the alignment angles on the front and rear suspensions.
- A scan tool is connected to the data link connector (DLC) under the dash to diagnose various electronic systems.
- A vehicle lift is used to raise vehicles off the floor so under-car service may be performed.

ASE-Style Review Questions

1. While discussing systems of weights and measures:
   Technician A says the international system (SI) is called the metric system.
   Technician B says every unit in the metric system can be divided or multiplied by 10.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
2. While discussing the metric system:
   Technician A says that 1 inch is equal to 2.54 millimeters.
   Technician B says that 1 meter is equal to 36.37 inches.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
3. When diagnosing a vehicle operational problem, the first step is to:
   A. Think of the possible causes of the problem.
   B. Perform diagnostic tests to locate the exact cause of the problem.
   C. Consult TSB information to find the cause of the problem.
   D. Identify the complaint.
4. When testing power steering pump pressure, the power steering gauge valve should be closed for a maximum of:
   A. 10 seconds. C. 25 seconds.
   B. 20 seconds. D. 35 seconds.
5. While discussing employer and employee responsibilities:
   Technician A says employers are required to inform their employees about hazardous materials in the shop.
   Technician B says that employers have no obligation to inform their employees about the safe operation of shop equipment.
   Who is correct?
   A. A only C. Both A and B

B. B only D. Neither A nor B

6. When connecting a scan tool to diagnose a computer-controlled suspension system on a 1998 vehicle:
   A. The scan tool power cord is connected to the cigarette lighter socket.
   B. The scan tool is connected to the DLC located under the dash.
   C. The ignition switch should be on when disconnecting the scan tool.
   D. On OBD II vehicles the 7-digit DTCs are displayed on the scan tool.
7. All these statements about suspension and steering tools are true EXCEPT:
   A. A plumb bob may be used for frame measurement.
   B. A tram gauge may be used to measure front wheel alignment.
   C. A scan tool may be used to diagnose electronically controlled suspension systems.
   D. A brake pedal jack may be used to apply the brakes during a wheel alignment.
8. When using a vehicle lift:
   A. The lift arms may be positioned on any strong chassis member.
   B. The safety catch must be engaged after the vehicle is raised on a lift.
   C. The vehicle hood should be open when raising a vehicle on a lift.
   D. The vehicle weight may exceed the maximum capacity of the lift.
9. When taking ASE certification tests:
   A. A technician must pass four of the eight ASE certification tests to receive a Master Technician's shoulder patch.
   B. Each ASE certification test contains 35 to 45 questions.
   C. An ASE specialty test is available in Advanced Engine Performance Specialist.
   D. Retesting at three-year intervals is required to maintain ASE certification.
10. When taking ASE certification tests:
    A. A technician must have four years of automotive repair experience before taking an ASE certification test.
    B. ASE may allow relevant training to be substituted for one year of work experience.
    C. On any ASE certification test, 90 percent of the questions are Technician A and Technician B type.
    D. Employers who employ ASE-certified technicians may display a green ASE seal of excellence.

Name ______________________________ Date ____________________

Raise a Car with a Floor Jack and Support It on Safety Stands

Upon completion of this job sheet, you should be able to raise the front and rear of a vehicle with a floor jack and support the vehicle on safety stands.

Tools and Materials

A car
Hydraulic floor jack
Four safety stands

Describe the Vehicle Being Worked On:

Year __________ Make ______________ Model ________________________
VIN ________________________ Engine type and size ___________________

This job sheet must be completed under the supervision of your instructor!

Procedure

Task Completed

1. Determine the proper vehicle floor jack lifting points in the car manufacturer's service manual. Proper front lifting point ________________________ Proper rear lifting point ________________________
2. Be sure the car is parked on a level shop floor surface with the parking brake applied. ☐
3. Place the floor jack under the proper lifting point on the front of the vehicle, and raise the floor jack pad until it contacts the lifting point. ☐
4. Release the parking brake and be sure the transmission is in neutral. Is the parking brake released? ☐ Yes ☐ No

   Is the transmission in neutral? ☐ Yes ☐ No

   Instructor check ____
5. Operate the floor jack and raise the vehicle to the desired height. Place safety stands under the proper support points on the vehicle chassis or suspension. ☐
6. Very slowly operate the release lever on the hydraulic floor jack to slowly lower the vehicle until the support points lightly contact the safety stands. Stop lowering the floor jack. ☐
7. Be sure the safety stands contact the proper support points on the vehicle, and check to be sure all the safety stand legs contact the shop floor evenly.

   Are the safety stands contacting the proper support points on the vehicle?
   ☐ Yes ☐ No

   Are all safety stand legs contacting the floor evenly? ☐ Yes ☐ No

   Instructor check ____

Task Completed

☐ 8. If the answer to both questions in step 7 is yes, very slowly operate the release lever on the hydraulic floor jack to slowly lower the vehicle until the vehicle weight is completely supported on the safety stands. Be sure all the safety stand legs are contacting the shop floor evenly, and then remove the floor jack.

☐ 9. Place the floor jack under the proper lifting point on the rear of the vehicle, and raise the floor jack pad until it contacts the lifting point.

10. Operate the floor jack, and raise the vehicle to the desired height. Place safety stands under the proper support points on the rear of the vehicle chassis or suspension.

Are the safety stands properly positioned? ☐ Yes ☐ No

Instructor check ________________________________

☐ 11. Very slowly operate the release lever on the hydraulic floor jack to slowly lower the vehicle until the rear support points lightly contact the safety stands. Stop lowering the floor jack.

12. Be sure the safety stands contact the proper rear support points on the vehicle, and check to be sure all the safety stand legs contact the shop floor evenly.

Are the safety stands contacting the proper support points on the vehicle?
☐ Yes ☐ No

Are all the safety stand legs contacting the floor evenly? ☐ Yes ☐ No

Instructor check ________________________________

☐ 13. If the answer to both questions in step 12 is yes, very slowly operate the release lever on the hydraulic floor jack to slowly lower the rear of the vehicle until the vehicle weight is completely supported on the safety stands. Be sure all the safety stand legs are contacting the shop floor evenly; then remove the floor jack.

Instructor's Response ________________________________

____

____

Name ______________________________ **Date** ____________________

Follow the Proper Procedure to Hoist a Car

Upon completion of this job sheet, you should be able to raise and lower a car on a hoist.

CAUTION: Do not raise a four-wheel-drive vehicle with a frame contact lift because this may damage axle joints.

Tools and Materials

Car
Lift with enough capacity to hoist the car

Describe the Vehicle Being Worked On:

Year __________ Make ______________ Model __________________________

VIN __________________________ Engine type and size ____________________

Procedure — Task Completed

1. Always be sure the lift is completely lowered before driving the car onto the lift. ☐
2. Do not hit or run over lift arms and adaptors when driving a car onto the lift. ☐
3. Have a coworker guide you when driving a car onto the lift. ☐

WARNING: Do not stand in front of a lift with the car coming toward you. This action may result in personal injury.

4. Be sure the lift pads on the lift are contacting the car manufacturer's recommended lifting points shown in the service manual. ☐

   Is the vehicle properly positioned on lift? ☐ Yes ☐ No

   Recommended front lifting points: ☐ Right side ☐ Left side

   Recommended rear lifting points: ☐ Right side ☐ Left side

   Are all four lift pads contacting the recommended lifting points? ☐ Yes ☐ No

   Instructor check ____

5. Be sure the doors and hood are closed, and be sure there are no people in the car. ☐
6. When a car is lifted a short distance off the floor, stop the lift and check the contact between the lift pads and the car chassis to be sure the lift pads are still on the recommended lifting points. ☐
7. Be sure there is adequate clearance between the top of the vehicle and the shop ceiling or components under the ceiling. ☐

Task Completed

☐ **8.** When a car is raised on a lift, be sure the safety mechanism is in place to prevent the lift from dropping accidentally.

Is the lift safety mechanism in place? ☐ Yes ☐ No

Instructor check ______________________________

List one precaution that must be observed when a front-wheel-drive vehicle is raised on a lift, and explain the reason for this precaution.

____

____

☐ **9.** Prior to lowering a car on a lift, always make sure there are no tools, objects, or people under the vehicle.

WARNING: Do not rock a car on a lift during a service job. This action may cause the car to fall off the lift, resulting in personal injury and vehicle damage.

WARNING: When a car is raised on a lift, removal of some heavy components may cause car imbalance on the lift, which may cause the car to fall off the lift, resulting in personal injury and vehicle damage.

☐ **10.** Be sure the lift is lowered completely and no lift components are contacting the vehicle before backing the vehicle off the lift.

Instructor's Response ______________________________

____

____

CAUTION: If the proper lifting points are not used, components under the vehicle such as brake lines or body parts may be damaged. Failure to use the recommended lifting points may cause the car to slip off the lift, resulting in severe vehicle damage and personal injury.

Name ______________________________ Date ____________________

Determine the Availability and Purpose of Suspension and Steering Tools

Procedure

Locate the following tools in your shop or tool room, and explain the purpose of each tool.

1. Stethoscope: available? ☐ Yes ☐ No
   Location____
   Purpose ____
2. Dial indicator for measuring ball joint wear: available? ☐ Yes ☐ No
   Location____
   Purpose ____
3. Ball joint removal and installing tools: available? ☐ Yes ☐ No
   Location____
   Purpose ____
4. Coil spring compressing tool: available? ☐ Yes ☐ No
   Location____
   Purpose ____
5. Power steering pressure gauge: available? ☐ Yes ☐ No
   Location____
   Purpose ____
6. Vacuum hand pump: available? ☐ Yes ☐ No
   Location____
   Purpose ____
7. Turning radius gauge: available? ☐ Yes ☐ No
   Location____
   Purpose ____
8. Brake pedal jack: available? ☐ Yes ☐ No
   Lcation____
   Purpose ____
9. Steering wheel locking tool: available? ☐ Yes ☐ No
   Location____
   Purpose ____

10. Scan tool: available? ☐ Yes ☐ No

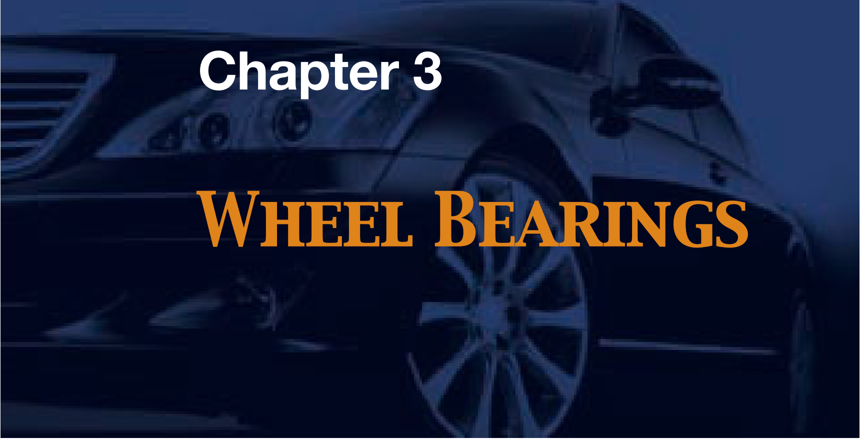
Location ____________________

Purpose ____________________

Instructor's Response ____________________

____

____



Chapter 3

Wheel Bearings

Upon completion and review of this chapter, you should be able to understand and describe:

- The purposes of a bearing.
- Three different types of bearing loads.
- The basic parts in ball bearings or roller bearings, and describe the purpose of each part.
- The action between the balls and the race when a ball bearing is rotating.
- The purposes of bearing snaprings, shields, and seals.
- The load-carrying capabilities of ball bearings, roller bearings, tapered roller bearings, and needle roller bearings.
- The advantage of tapered roller bearings compared to other types of bearings.
- Seal design and purpose.
- The purpose of the garter spring behind a lip seal.
- The purpose of flutes on seal lips.
- Two different types of rear axle bearings in rear-wheel-drive cars, and give the seal location for each bearing type.

Introduction

Many different types of bearings are used in the automobile. A bearing may be defined as a component that supports and guides one of these parts:

1. Pivot
2. Wheel
3. Rotating shaft
4. Oscillating shaft
5. Sliding shaft

While a bearing is supporting and guiding one of these components, the bearing is designed to reduce friction and support the load applied by the component and related assemblies. Since the bearing reduces friction, it also decreases the power required to rotate or move the component. Bearings are precision-machined assemblies, which provide smooth operation and long life. When bearings are properly installed and maintained, bearing failure is rare.

Author's Note: Only 21 percent of the power developed by a vehicle engine actually gets to the drive wheels. Much of the engine energy is lost in overcoming friction and wind resistance. The U.S. Department of Energy (DOE) is working with a major bearing manufacturer to explore the use and advantage of roller bearings to reduce friction in vehicle engines. The DOE estimates that if all vehicle engines used roller-bearing, low-friction technology, 100 million barrels of oil could be saved in a year.

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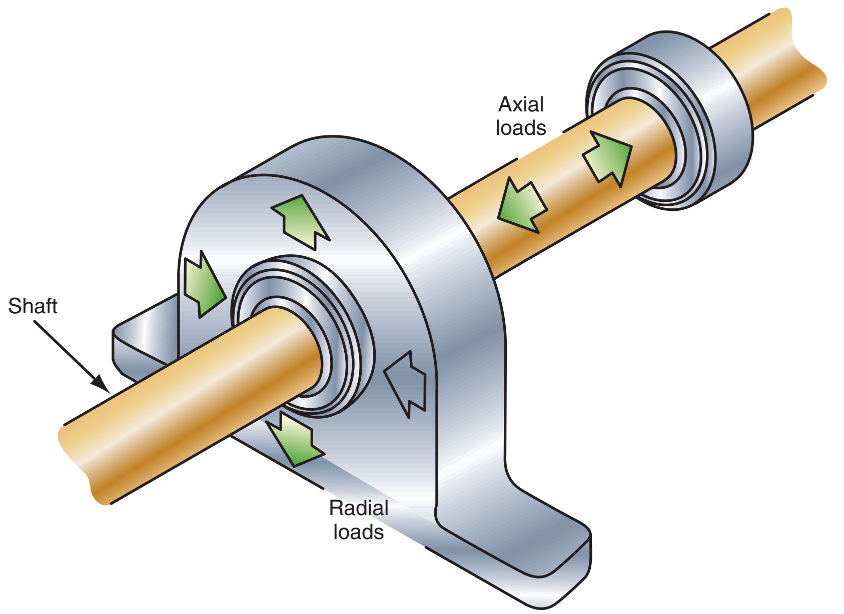

FIGURE 3-1 **Types of bearing loads.**

A **thrust bearing load** may be referred to as an axial load.

Ball bearings have round steel balls between the inner and outer races.

The **inner race** supports the inner side of the rolling elements in a bearing.

The **rolling elements** are the precision-machined balls or rollers between the inner and outer bearing races.

The **separator** keeps the rolling elements equally spaced in a bearing.

The **outer race** supports the outer side of the rolling elements and positions the bearing properly in the housing.

A **single-row ball bearing** has one row of balls between the inner and outer races.

Bearing Loads

When a bearing load is applied in a vertical direction on a horizontal shaft, it is called a **radial bearing load**. If the vehicle weight is applied straight downward on a bearing, this weight is a radial load on the bearing. A **thrust bearing load** is applied in a horizontal direction (Figure 3-1). For example, while a vehicle is turning a corner, horizontal force is applied to the front wheel bearings. When an **angular bearing load** is applied, the angle of the applied load is somewhere between the horizontal and vertical positions.

Ball Bearings

Front and rear wheel bearings may be **ball bearings** or roller bearings. Either type of bearing contains these basic parts:

1. Inner race, or cone
2. Rolling elements, balls, or rollers
3. Separator, also called a cage or retainer
4. Outer race, or cup

The **inner race** is an accurately machined component. The inner surface of the race is mounted on the shaft with a precision fit. The **rolling elements** are mounted on a very smoothly machined surface on the inner race. The surfaces on the rolling elements and the inner and outer races are case hardened to provide long bearing life. Positioned between the inner and outer races, the **separator** retains the rolling elements and keeps them evenly spaced. The rolling elements have precision-machined surfaces, and these elements are mounted between the inner and outer races. The **outer race** is the bearing's exterior ring. Both sides of this component have precision-machined surfaces. The outer surface of this race supports the bearing in the housing, and the inner surface is in contact with the rolling elements.

A **single-row ball bearing** has a crescent-shaped machined surface in the inner and outer races in which the balls are mounted (Figure 3-2). When a ball bearing is at rest, the load is distributed equally through the balls and races in the contact area. When one of the races and the balls begin to rotate, the bearing load causes the metal in the race to bulge out in front of the ball and flatten out behind the ball (Figure 3-3). This action

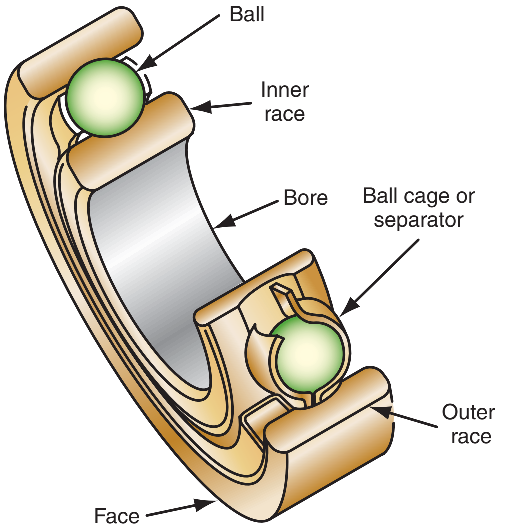

FIGURE 3-2 **Parts of a ball bearing.**

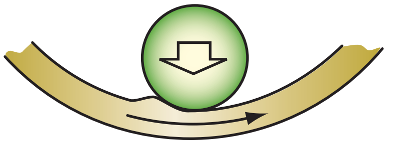

FIGURE 3-3 **When a load is applied to a ball bearing, the metal in the race bulges out in front of the ball and flattens out behind the ball.**

creates a certain amount of friction within the bearing, and the same action is repeated for each ball while the bearing is rotating. If metal-to-metal contact is allowed between the balls and the races, these components will experience very fast wear. Therefore, bearing lubrication is extremely important to eliminate metal-to-metal contact in the bearing and reduce wear.

A ball bearing is designed primarily to handle radial loads. However, this type of bearing can also withstand a considerable amount of thrust load in either direction, even at high speeds. A maximum capacity ball bearing has extra balls for greater radial load-carrying capacity. Ball bearings are available in many different sizes for various applications (Figure 3-4).

FIGURE 3-4 **A ball bearing.**

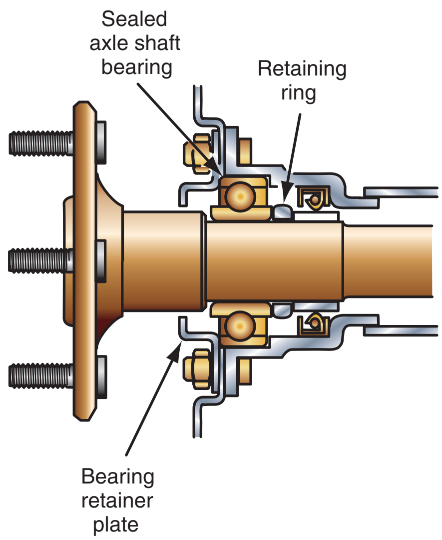

FIGURE 3-5 **Some rear axle bearings are sealed on both sides and retained on the axle with a retainer ring.**

A **snapring** is made from spring steel and fits into a groove to retain a bearing on a shaft.

Bearing shields may be positioned between the inner and outer bearing races on the outside of the rolling elements.

A **bearing seal** may be mounted on the outside of the rolling elements. The seal is attached to the outer race, and the seal lip contacts the inner race.

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A **roller bearing** is sometimes called a nontapered roller bearing.

Double-row ball bearings contain two rows of balls side by side. As in the single-row ball bearing, the balls in the double-row bearing are mounted in crescent-shaped grooves in the inner and outer races. The double-row ball bearing can support heavy radial loads and withstand thrust loads in either direction.

Ball Bearing Seals, Shields, and Snaprings

For some applications, a ball bearing is held in place with a **snapring**. A groove is cut around the outside surface of the outer race, and the snapring is mounted in this groove. The snapring may fit against a machined housing surface, or the outer circumference of the snapring may be mounted in a groove in the housing. Ball bearings retained with a snapring are not used on wheels because they are not designed to withstand high thrust loads encountered by wheel bearings.

Bearing shields cover the space between the two bearing races on one, or both, sides of the bearing. These shields are usually attached to the outer race, but space is left between the shield and the inner race. Bearing shields prevent dirt from entering the bearing, but excess lubrication can still flow through the bearing.

A **bearing seal** is a circular metal ring with a sealing lip on the inner edge. The seals are usually attached to the outer bearing race on each side of the bearing, and the lip surface contacts the inner race. The seal lip may have single, double, or triple lips made of synthetic or nonsynthetic rubber or elastomers. Lubricant is retained in the bearing by the seal, and the seal also keeps moisture, dirt, and contaminants out of the bearing. Some rear axle bearings on rear-wheel drive cars are sealed on both sides and retained on the axle with a retainer ring (Figure 3-5).

ROLLER BEARINGS

Roller Bearing

A **roller bearing** contains precision-machined rollers that have the same diameter at both ends. These rollers are mounted in square-cut grooves in the outer and inner races (Figure 3-6). In the roller bearing, the races and rollers run parallel to one another. Roller bearings are designed primarily to carry radial loads, but they can withstand some thrust load. Since ball bearings do not withstand high thrust loads, they are usually not used in wheel bearings.

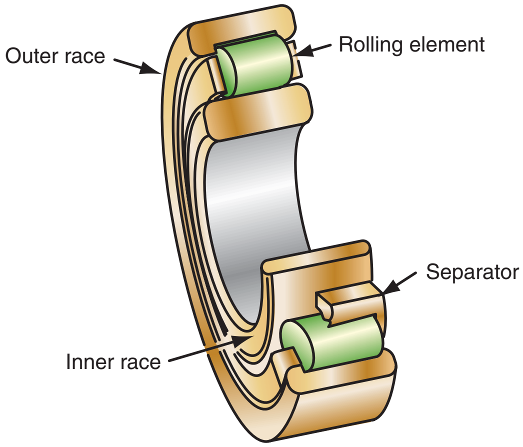

FIGURE 3-6 **Parts of a roller bearing.**

Tapered Roller Bearing

In a **tapered roller bearing**, the inner and outer races are cone shaped. If imaginary lines extend through the inner and outer races, these lines taper and eventually meet at a point extended through the center of the bearing (Figure 3-7). The most important advantage of the tapered roller bearing compared to other bearings is an excellent capability to carry radial, thrust, and angular loads. In the tapered roller bearing, the rollers are mounted on cone-shaped precision surfaces in the outer and inner races. The bearing separator has an open space over each roller (Figure 3-8). Grooves cut in the side of the separator roller openings match the curvature of the roller. This design allows the rollers to rotate evenly without interference between the rollers and the separator. Lubrication and proper endplay

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A **tapered roller bearing** has tapered rollers between the inner and outer races. Tapered surfaces on the races match the tapered roller surfaces.

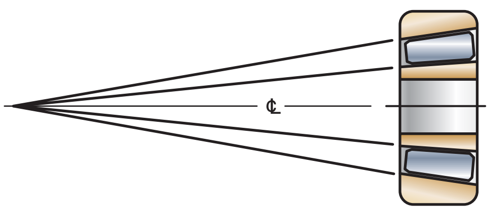

FIGURE 3-7 **Imaginary lines extending from tapered roller bearing races eventually meet at a point extending from the bearing center.**

FIGURE 3-8 **Tapered roller bearings.**

FIGURE 3-9 **Needle roller bearing.**

adjustment are critical on tapered roller bearings. A tapered roller bearing may be called a cup and cone.

Needle Roller Bearings

A **needle roller bearing** contains many small-diameter steel rollers in a thin outer race. This type of bearing is very compact, and it is used in steering gears where mounting space is limited. Most needle roller bearings do not have a separator, but the steel rollers push against each other and maintain the roller position. Rather than having an inner race, a machined surface on the mounting shaft contacts the inner surface of the rollers (Figure 3-9). The needle roller bearing is designed to carry radial loads; it does not withstand thrust loads.

WARNING: Never strike a roller bearing with a steel hammer. This action may cause the bearing to shatter, resulting in severe personal injury.

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WARNING: Spinning a roller bearing with compressed air may rotate the bearing at extremely high speed and cause the bearing to disintegrate, resulting in serious personal injury.

Springless seals do not have a garter spring behind the seal lip.

A **spring-loaded seal** has a garter spring behind the seal lip.

A **garter spring** is a circular coil spring mounted behind a seal lip.

Seals

Seals are designed to keep lubricant in the bearing and prevent dirt particles and contaminants from entering the bearing. Wheel bearing seals are mounted in front and rear wheel hubs, and in rear axle housings on rear-wheel-drive cars. The metal seal case has a surface coating that resists corrosion and rust and acts as a bonding agent for the seal material. Seals have many different designs, including single lip, double lip, and fluted. The seal material is usually made of a synthetic rubber compound such as nitrile, silicon, polyacrylate, or a fluoroelastomer such as Viton. The actual seal material depends on the lubricant and contaminants that the seal encounters. All seals may be divided into two groups, springless and spring loaded. **Springless seals** are used in some front or rear wheel hubs, where they seal a heavy lubricant into the hub (Figure 3-10).

In a **spring-loaded seal**, the **garter spring** behind the seal provides additional force on the seal lip to compensate for lip wear, shaft movement, and bore eccentricity (Figure 3-11).

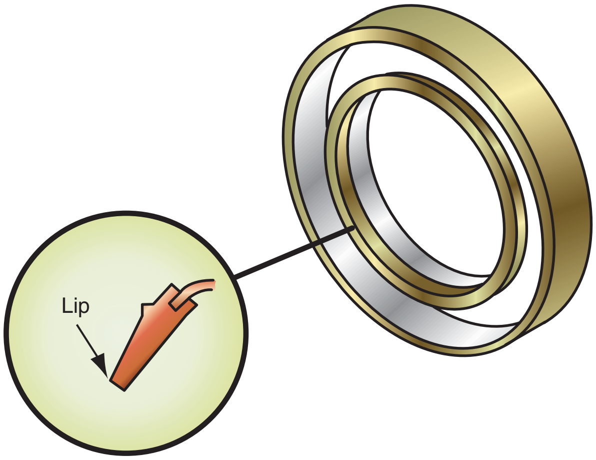

FIGURE 3-10 **Springless seal.**

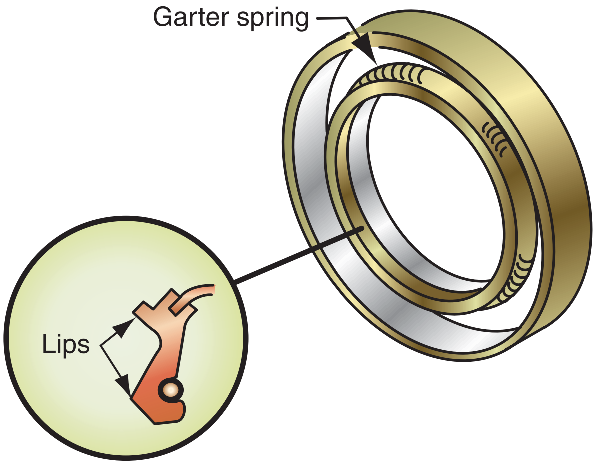

FIGURE 3-11 **Spring-loaded seal.**

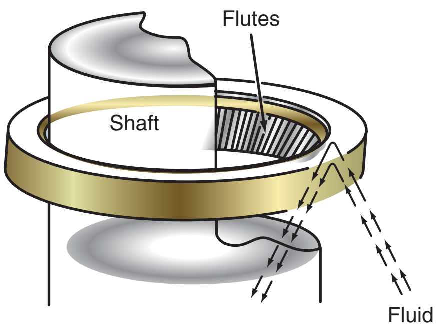

FIGURE 3-12 **Fluted lip seal redirect oil back into the housing.**

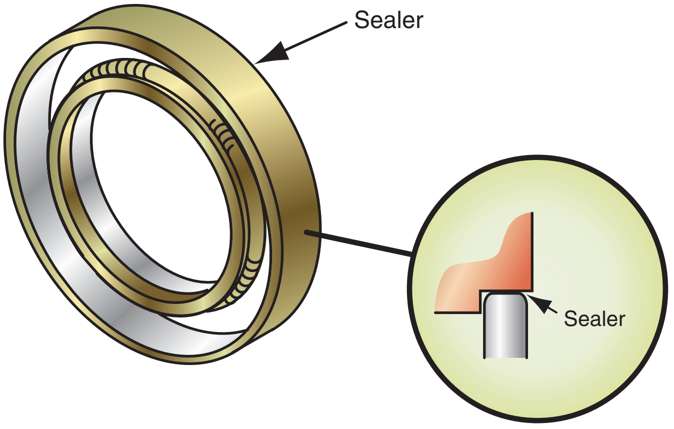

FIGURE 3-13 **Sealer painted on the seal case prevents leaks between the case and the housing.**

A **fluted lip seal** may be used to direct oil back into a housing. This seal design provides a pumping action to redirect the oil back into the housing (Figure 3-12).

Some seals have a sealer painted on the outside surface of the metal seal housing. When the seal is installed, this sealer prevents leaks between the seal case and the housing (Figure 3-13).

A **fluted lip seal** has small ridges on the outer lip surface.

Wheel Bearings

Some front-wheel-drive vehicles have front wheel bearing and hub assemblies that are bolted to the steering knuckles (Figure 3-14). The bearings are lubricated and sealed, and the complete bearing and hub assembly is replaced as a unit. The **bearing hub unit** is more compact than other types of wheel bearings mounted in the wheel hub. This type of bearing contains two rows of ball bearings with an angular contact angle of 32° (Figure 3-15). The inner bearing assembly bore is splined, and the inner ring extends to the outside to form a flange and spigot. The flange attached to the outer ring contains bolt holes, and bolts extend through these holes into the steering knuckle. This type of bearing attachment allows the bearing to become a structural member of the front suspension. Since the bearing outer ring is self-supporting, the main concern in knuckle design is fatigue strength rather than stiffness. The drive axle shaft transmits torque to the inner

A **bearing hub unit** is a one-piece bearing and hub assembly that supports a front or rear wheel.

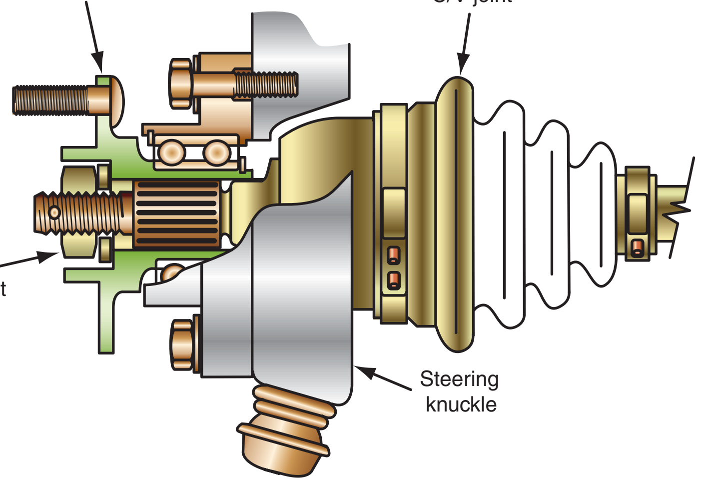

FIGURE 3-14 **Wheel bearing and hub assembly.**

FIGURE 3-15 **Double-row, sealed wheel bearing hub unit.**

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bearing race. This shaft is not designed to hold the bearing together. This type of wheel bearing is designed for mid-sized front-wheel-drive cars.

Each front drive axle has splines that fit into matching splines inside the bearing hubs (Figure 3-16). A hub nut secures the drive axle into the inner bearing race. Some wheel bearing hubs contain a wheel speed sensor for the antilock brake system (ABS).

Some front-wheel-drive vehicles have a sealed bearing unit that is pressed into the steering knuckle (Figure 3-17). The wheel hub is pressed into the inner bearing race, and the drive axle is splined into the hub. This type of bearing is designed for smaller front-wheel-drive cars. These bearings may contain two rows of ball bearings, or two tapered roller bearings and a split inner race (Figure 3-18). The bearing containing two tapered roller bearings has more radial load capacity than the double-row ball bearing. However, the tapered roller bearing is more sensitive to misalignment. Both sides of the bearing are sealed, and a seal

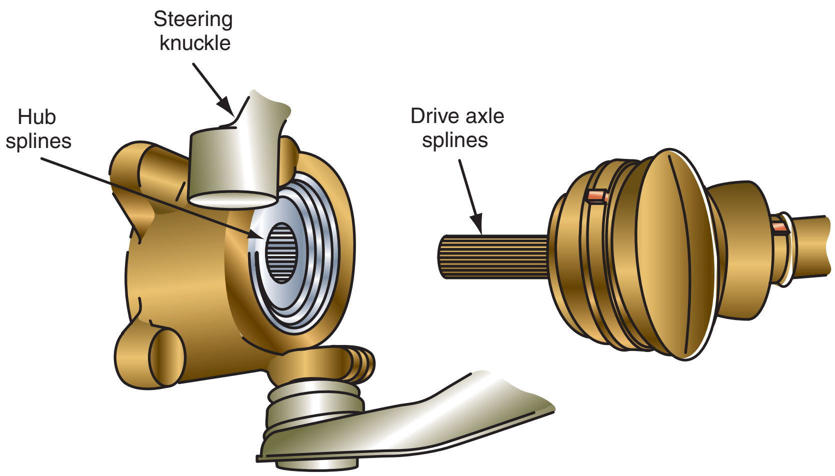

FIGURE 3-16 **Front drive shaft installed in wheel bearing hub.**

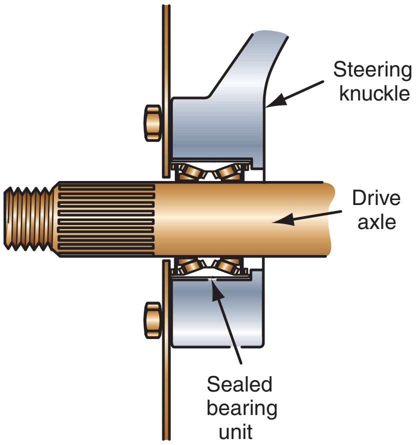

FIGURE 3-17 **Steering knuckle with pressed-in bearing.**

FIGURE 3-18 **Cutaway view of front wheel bearing that is pressed into the steering knuckle.**

is positioned behind the bearing in the steering knuckle to keep contaminants out of the bearing area.

Front Steering Knuckles with Two Separate Tapered Roller Bearings

Other front-wheel-drive vehicles have two separate tapered roller bearings mounted in the steering knuckles. The bearing races are pressed into the steering knuckle, and seals are located in the knuckle on the outboard side of each bearing (Figure 3-19). Correct bearing endplay adjustment is supplied by the hub nut torque. The wheel hub is pressed into the inner bearing races, and the drive axle splines are meshed with matching splines in the wheel hub.

Wheel Hubs with Two Separate Tapered Roller Bearings

Many rear-wheel-drive cars have two tapered roller bearings in the front hubs that support the hubs and wheels on the spindles. This type of front wheel bearing has the bearing races pressed into the hub. A grease seal is pressed into the inner end of the hub to prevent grease leaks and keep contaminants out of the bearings. The hub and bearing assemblies are retained on the spindle with a washer, adjusting nut, nut lock, and cotter pin. The adjusting nut must be adjusted properly to provide the correct bearing endplay. A grease cap is pressed into the outer end of the hub to prevent bearing contamination (Figure 3-20).

A Bit of History

Nearly all rear-wheel-drive cars have two serviceable tapered roller bearings or ball bearings in the front wheel hubs. Most front-wheel-drive cars have sealed bearing hubs on the front wheels, and some have these units on the rear wheels. These sealed bearing hub units have largely replaced the tapered roller bearings or ball bearings in the front wheel hubs.

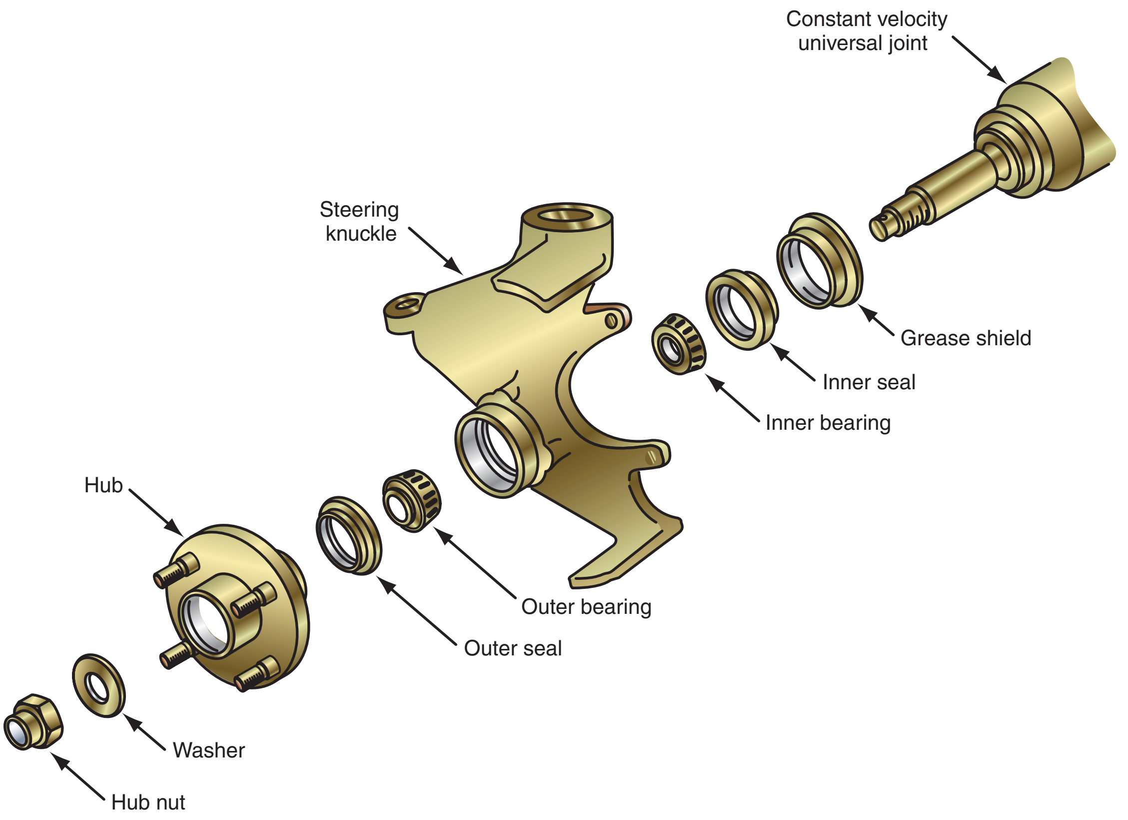

FIGURE 3-19 **Steering knuckle with two separate tapered roller bearings.**

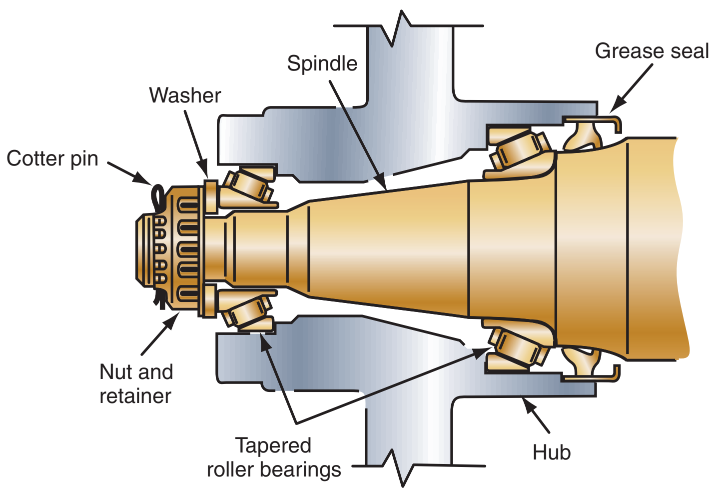

FIGURE 3-20 **Front wheel bearing assembly, rear-wheel-drive car.**

Some front-wheel-drive cars have two tapered roller bearings in the rear wheel hubs that are very similar to the front wheel bearings in Figure 3-20. The two tapered roller bearings in the rear wheel of a front-wheel-drive car are shown (Figure 3-21).

AUTHOR'S NOTE: An understanding of wheel bearings and related service procedures is critical to maintain vehicle safety! If the technician's knowledge of wheel bearings and appropriate service procedures is inadequate, bearing failure may occur. Wheel bearing failure may cause a wheel to fly off a vehicle with disastrous results!

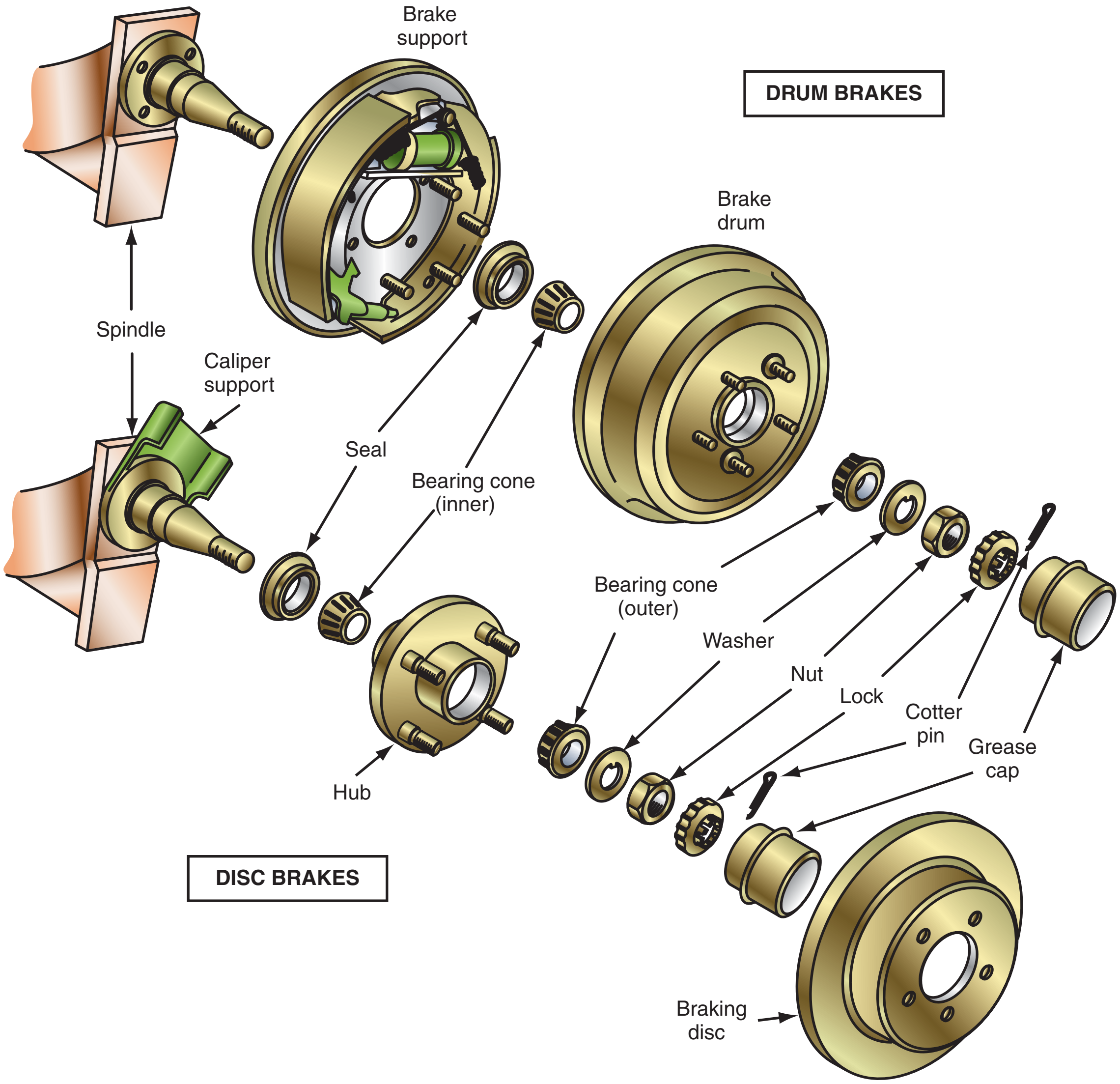

FIGURE 3-21 **Rear wheel hub with tapered roller bearings for drum or disc brakes, front-wheel-drive car.**

Rear-Axle Bearings

On many rear-wheel-drive cars, the rear axles are supported by roller bearings mounted near the outer ends of the axle housing. The outer bearing race is pressed into the housing, and a machined surface on the axle contacts the inner roller surface. A seal is mounted in the axle housing on the outboard side of each bearing (Figure 3-22). This type of axle bearing is usually not sealed, and lubricant in the differential and rear axle housing provides axle bearing lubrication. The seals prevent lubricant leaks from the outer ends of the axle housing and keep dirt out of the bearings.

Other **rear-axle bearings** on rear-wheel-drive vehicles have sealed roller bearings pressed onto the rear axles. These axle bearings are sealed on both sides, and an adapter ring is pressed onto the axle on the inboard side of the bearing (Figure 3-23). The outer bearing race is mounted in the rear axle housing with a light press fit, and a seal is positioned in the housing on the inboard side of the bearing and adapter ring. A retainer plate is mounted between the bearing and the outer end of the axle. This retainer plate is bolted to the axle housing to retain the axle in the housing.

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Rear-axle bearings support the rear axles in the rear axle housing on rear-wheel-drive vehicles.

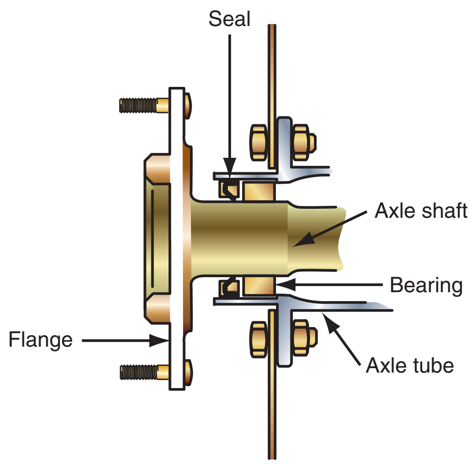


FIGURE 3-22 **Rear-axle bearing, rear-wheel-drive car.**

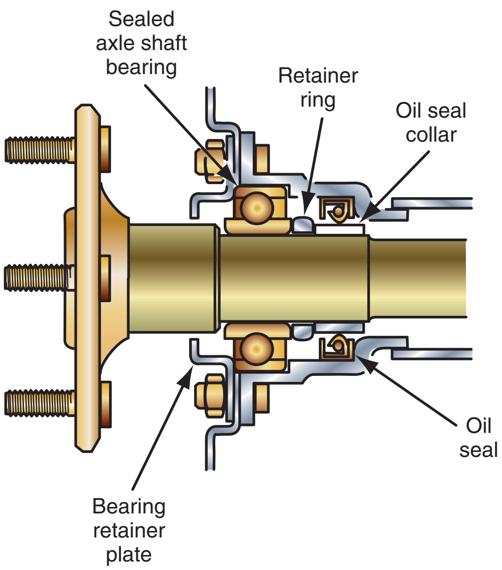


FIGURE 3-23 **Rear-axle bearing and retainer.**

A **lithium-based grease** has a specific amount of lithium mixed with the lubricant.

A **sodium-based grease** has a specific amount of sodium mixed with the lubricant.

The **Society of Automotive Engineers (SAE)** is responsible for the establishment of many automotive standards.

The **American Petroleum Institute (API)** is responsible for establishing standards related to oils and lubricants.

CAUTION: If a bearing is operated without proper lubrication, bearing life will be very short.

Bearing Lubrication

Proper bearing lubrication is extremely important to maintain bearing life. Bearing lubricant reduces friction and wear, dissipates heat, and protects surfaces from dirt and corrosion. Sealed or shielded bearings are lubricated during the manufacturing process, *and no attempt should be made to wash these bearings or pack them with grease*.

Bearings that are not sealed or shielded require cleaning and repacking at intervals specified by the vehicle manufacturer. *Always use the bearing grease specified by the vehicle manufacturer*. Bearing lubricants may be classified as greases or oils. Many wheel bearings require **lithium-based** or **sodium-based grease**.

New bearings usually have a protective coating to prevent rust and corrosion. This coating should not be washed from the bearing. When rear-axle bearings are lubricated from the differential housing, the type and level of oil in the housing are important.

Vehicle manufacturers usually recommend a **Society of Automotive Engineers (SAE)** No. 90 or SAE No. 140 hypoid gear oil in the differential. In very cold climates, the manufacturer may recommend an SAE No. 80 differential gear oil. The **American Petroleum Institute (API)** classifies gear lubricants as GL-1, GL-2, GL-3, GL-4, and GL-5. The GL-4 lubricant is used for hypoid gears under normal conditions. The GL-5 lubricant is used in heavy-duty hypoid gears. Always use the vehicle manufacturer's specified differential gear oil.

The differential should be filled until the lubricant is level with the bottom of the filler plug opening in the differential housing. If the differential is overfilled, the bearings and seals may have excessive lubricant. Under this condition, the lubricant may leak past the seal. When the lubricant level is low in the differential, the lubricant may not be available in the axle housings. When this condition exists, the bearings do not receive enough lubrication and bearing life is shortened.

Summary

- A bearing reduces friction, carries a load, and guides certain components such as pivots, shafts, and wheels.
- Radial bearing loads are applied in a vertical direction.
- Thrust bearing loads are applied in a horizontal direction.
- Angular bearing loads are applied at an angle between the vertical and horizontal.
- The inner bearing race is positioned at the center of the bearing and supports the rolling elements.
- The rolling elements in a bearing are positioned between the inner and outer races.
- The bearing separator keeps the rolling elements evenly spaced.
- The outer bearing race forms the outer ring on a bearing.
- A cylindrical ball bearing is designed primarily to withstand radial loads, but these bearings can handle a considerable thrust load.
- A snapring can be mounted in a groove in the outer bearing race, and the snapring retains the bearing in the housing.
- A bearing shield prevents dirt from entering the bearing, but it is not designed to keep lubricant in the bearing.
- Bearing seals keep lubricant in the bearing and prevent dirt from entering the bearing.
- Roller bearings are designed primarily to carry radial loads, but they can handle some thrust loads.
- Tapered roller bearings have excellent radial, thrust, and angular load-carrying capabilities.
- Needle roller bearings are very compact and are designed to carry radial loads. They will not carry thrust loads.
- Springless seals are used for wheel bearing seals in some wheel hubs.
- The garter spring provides additional force on the seal lip to compensate for lip wear, shaft movement, and bore eccentricity.
- Flutes on seal lips provide a pumping action to direct oil back into a housing.
- Bearing hub units are compact compared to bearings that are mounted in the wheel hub. This compactness makes bearing hub units suitable for front-wheel-drive cars.
- Some bearing hub units are bolted to the steering knuckle; other bearing hub units are pressed into the steering knuckle.
- Some steering knuckles contain two separate tapered roller bearings.
- Rear-axle bearings are mounted between the drive axles and the housing on rear-wheel-drive cars.

Terms to Know

American Petroleum Institute (API)
Angular bearing load
Ball bearings
Bearing hub unit
Bearing seals
Bearing shields
Double-row ball bearings
Fluted lip seal
Garter spring
Inner race
Lithium-based grease
Needle roller bearing
Outer race
Radial bearing load
Rear-axle bearings
Roller bearing
Rolling elements
Separator
Single-row ball bearing
Snapring
Society of Automotive Engineers (SAE)
Sodium-based grease
Springless seals
Spring-loaded seal
Tapered roller bearing
Thrust bearing load

Review Questions

Short Answer Essays

1. Define a radial bearing load.
2. Define a thrust bearing load, and give another term for this type of load.
3. Explain an angular bearing load.
4. Describe the main parts of a bearing, including the location and purpose of each part.
5. Describe the difference between a maximum-capacity ball bearing and an ordinary ball bearing.
6. Explain the design and purpose of bearing seals.
7. Explain the purpose of the sealer on the outside surface of a seal housing.
8. Describe the advantage of a bearing hub unit compared to bearings that were mounted in the wheel hub.

9. Explain how the proper bearing endplay adjustment is obtained when two tapered roller bearings are mounted in the steering knuckle.
10. Describe two different types of rear-axle bearings on rear-wheel-drive cars.

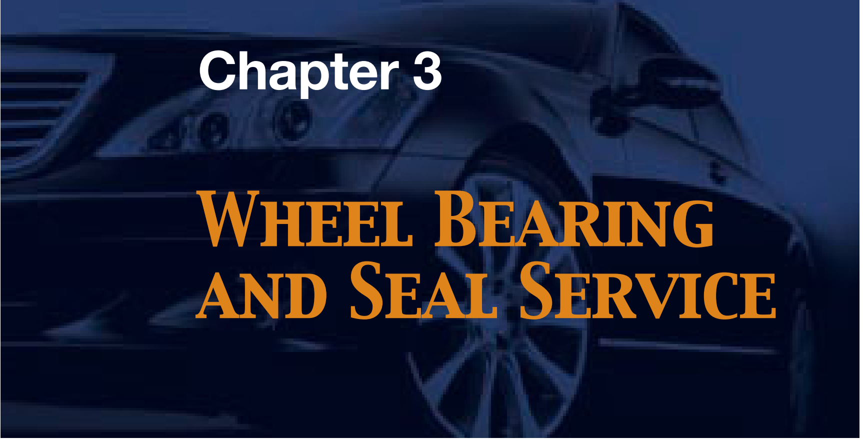
Fill-in-the-Blanks

1. A bearing can be described as a component that supports a _______________, _______________, or _______________.
2. A bearing is designed to support a load and _______________.
3. An angular bearing load is applied at an angle between the _______________ and the _______________.
4. A ball bearing is designed primarily to withstand _______________ loads.
5. A bearing shield is attached to the _______________ bearing race.
6. Lubrication and proper _______________ adjustment are important on tapered roller bearings.
7. A needle roller bearing is not designed to carry _______________ loads.
8. A springless seal may be used to seal a _______________ lubricant into a hub.
9. When a vehicle is turning a corner, the front wheel bearings must carry a _______________ load.
10. When a rear-wheel-drive vehicle has cylindrical roller bearings mounted in the rear axle housing, the inner surface on the rollers contacts a machined surface on the _______________.

Multiple Choice

1. A tapered roller bearing has:
   - A. Rollers that have the same diameter at both ends.
   - B. Excellent ability to carry radial, thrust, and angular loads.
   - C. Horizontal inner surfaces of the inner and outer races.
   - D. A separator that allows the rollers to lightly contact each other.
2. A spring-loaded seal compensates for all of these conditions EXCEPT:
   - A. Seal lip wear.
   - B. Shaft movement.
   - C. Bore eccentricity.
   - D. Wear on the seal bore.
3. When two separate tapered roller bearings are located in a front steering knuckle on a front-wheel-drive car, the wheel bearing endplay adjustment is provided by:
   - A. The bearing race position.
   - B. Wheel nut torque.
   - C. Hub nut torque.
   - D. Wheel hub position.
4. A rear-wheel hub contains two tapered roller bearings on a front-wheel-drive car. This type of wheel hub has:
   - A. An adjusting nut to adjust the wheel bearing endplay.
   - B. A lock washer to retain the adjusting nut.
   - C. A staked-type nut lock.
   - D. A seal in the outer end of the hub to prevent grease contamination.
5. On a rear-wheel-drive car, the rear axle bearings have been damaged by excessive overheating. The most likely cause of this condition is:
   - A. Insufficient rear-axle bearing endplay.
   - B. Excessive lubricant level in the differential.
   - C. Low lubricant level in the differential.
   - D. Worn rear axle seals.
6. When inspecting and servicing bearings:
   - A. Some rear-wheel-drive vehicles have rear-axle bearings that are sealed on both sides.
   - B. In a sealed bearing, the seal is usually attached to the inner race.
   - C. Endplay adjustment is not critical on tapered roller bearings.
   - D. A roller bearing can be removed by striking it with a steel hammer.

7. All of these statements about bearings are true EXCEPT:
   A. Tapered roller bearings have excellent capability to carry radial, thrust, and angular loads.
   B. Ball bearings are used in most wheel bearings.
   C. A roller bearing has rollers with the same diameter at each end.
   D. In a tapered roller bearing, the openings in the separator grooves match the curvature of the rollers.
8. While inspecting and servicing wheel hub seals:
   A. Many wheel hub seal lips are made from a plastic compound.
   B. Springless seals may be used in applications where they must seal a light fluid.
   C. A spring-loaded seal helps compensate for wheel hub bore eccentricity.
   D. The sealer on the outer surface of a seal housing improves seal and hub bore alignment.
9. When inspecting and servicing front wheel bearings on front-wheel-drive cars:
   A. Some one-piece front wheel bearing hubs are bolted to the front strut.
   B. In a one-piece front wheel bearing hub, the outer end of the drive axle is splined to the outer bearing race.
   C. When the steering knuckle contains two tapered roller bearings, the torque on the drive axle nut does not affect bearing endplay.
   D. Some front wheel bearings mounted in the steering knuckle contain two tapered roller bearings with a split inner race.
10. When inspecting and servicing rear wheel bearings on rear-wheel-drive cars:
    A. On some rear wheel bearings, a threaded adapter ring retains the bearing on the axle shaft.
    B. Roller-type rear-axle bearings may be lubricated from the oil supply in the differential.
    C. A GL-2 lubricant is recommended in hypoid-type differentials.
    D. An SAE 50 gear oil is recommended in many differentials.



Chapter 3

Wheel Bearing and Seal Service

Upon completion and review of this chapter, you should be able to:

- Diagnose bearing defects.
- Clean and repack wheel bearings.
- Reassemble and adjust wheel bearings.
- Remove and replace wheel bearing seals.
- Diagnose wheel bearing problems.
- Diagnose problems in wheel bearing hub units.
- Remove and replace front drive axles.
- Remove and replace wheel bearing hub units.
- Remove and replace rear-axle bearings on rear-wheel-drive cars.

Technicians must accurately diagnose wheel bearing problems to avoid repeat bearing failures, and thus provide customer satisfaction. Accurate wheel bearing service procedures are essential to maintain vehicle safety! Improper wheel bearing service may cause brake problems, steering complaints, and premature bearing failure. Improper wheel bearing service may even cause a wheel to fly off a vehicle, resulting in personal injury and vehicle damage. A knowledge of drive axle removal is necessary to service the front wheel bearings on front-wheel-drive vehicles, because the drive axle must be removed from the front hub to service the wheel bearings. Similarly, technicians must also understand rear-axle bearing service procedures on rear-wheel-drive vehicles.

BASIC TOOLS

Basic technician's tool set

Service manual

Inch-pound torque wrench

Foot-pound torque wrench

Fine-toothed round and flat files

Wheel bearing grease

Differential lubricant

Diagnosis of Bearing Defects

Bearings are designed to provide long life, but there are many causes of premature bearing failure. If a bearing fails, the technician must decide if the bearing failure was caused by normal wear or if the bearing failed prematurely. For example, if a front wheel bearing fails on a car that is one year old with an original odometer reading of 15,000 miles (24,000 kilometers), experience tells us the bearing failure is premature, because front wheel bearings normally last for a much longer mileage period. Always listen to the customer's complaints, and obtain as much information as possible from the customer. Ask the customer specific questions about abnormal or unusual vehicle noises and operation. If a bearing fails prematurely, there must be some cause for the failure.

Bearing galling refers to metal smears on the ends of the rollers.

The causes of premature bearing failure are:

1. Lack of lubrication
2. Improper type of lubrication
3. Incorrect endplay adjustment (where applicable)
4. Misalignment of related components, such as shafts or housings
5. Excessive bearing load

Bearing abrasive step wear is a fine circular wear pattern on the ends of the rollers.

Bearing etching appears as a loss of material on the bearing rollers and races. Bearing surfaces are gray or grayish black.

Bearing indentations are surface depressions on the rollers and races.

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Bearing brinelling may be caused by the continuous vibration when transporting new vehicles by rail or truck from the factory to the dealership.

CAUTION: Never wash a sealed bearing or a bearing that is shielded on both sides because solvent may enter the bearing and destroy the lubricant in the bearing, resulting in very short bearing life.

6. Improper installation or service procedures
7. Excessive heat
8. Dirt or contamination

When a bearing fails prematurely, the technician must correct the cause of this failure to prevent the new bearing from failing. The types of bearing failures and the necessary corrective service procedures are provided in Figure 3-1 and Figure 3-2. **Bearing fatigue spalling** appears as flaking of surface metal on bearing rollers and races. **Bearing brinelling** shows up as straight-line indentations on the races and rollers. **Bearing smears** appear as metal loss in a circular, blotched pattern around the bearing races and rollers. **Bearing frettage** shows up as a fine, corrosive wear pattern around the bearing races and rollers. This wear pattern is circular on the races.

The first indication of bearing failure is usually a howling noise while the bearing is rotating. The howling noise will likely vary depending on the bearing load. A front wheel bearing usually provides a more noticeable howl when the vehicle is turning a corner, because this places additional thrust load on the bearing. A defective rear-axle bearing usually provides a howling noise that is more noticeable at lower speeds. The howling noise is more noticeable when driving on a narrow street with buildings on each side, because the noise vibrates off the nearby buildings. A rear-axle bearing noise is present during acceleration and deceleration, because the vehicle weight places a load on the bearing regardless of the operating condition. The rear-axle bearing noise may be somewhat more noticeable during deceleration because there is less engine noise at that time.

Service and Adjustment of Tapered Roller Bearing-Type Wheel Bearings

Cleaning Bearings

WARNING: Always wear safety goggles when working in the shop.

WARNING: Do not aim compressed air directly toward any part of your body. Compressed air can penetrate human flesh and enter the blood stream with very serious consequences.

WARNING: Do not spin the bearing at high speed with compressed air. Bearing damage or disintegration may result. Bearing disintegration may cause serious personal injury.

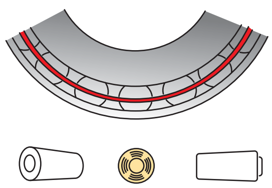
WARNING: Never strike a bearing with a ball peen hammer. This action will damage the bearing and the bearing may shatter, causing severe personal injury.

Two separate tapered roller bearings are used in the front wheel hubs of many rear-wheel-drive cars. The rear wheel hubs on some front-wheel-drive cars have the same type of bearings. Similar service and adjustment procedures apply to these tapered roller bearings.

These bearings should be cleaned, inspected, and packed with wheel bearing grease at the vehicle manufacturer's recommended service intervals. Pry the grease seal out of the inner hub opening with a seal removal tool, and discard the seal. This seal should always be replaced when the bearings are serviced. Do not attempt to wash sealed bearings or bearings that are shielded on both sides. If a bearing is sealed on one side, it may be washed in solvent and repacked with grease.

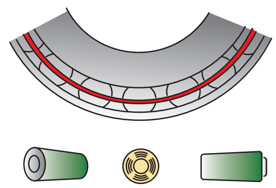
TAPERED ROLLER BEARING DIAGNOSIS

Consider the following factors when diagnosing bearing condition:
1. General condition of all parts during disassembly and inspection.
2. Classify the failure with the aid of the illustrations.
3. Determine the cause.
4. Make all repairs following recommended procedures.



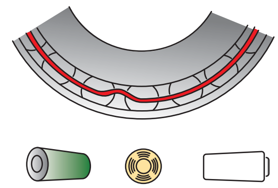
ABRASIVE STEP WEAR

Pattern on roller ends caused by fine abrasives. Clean all parts and housings, check seals and bearings, and replace if leaking, rough, or noisy.



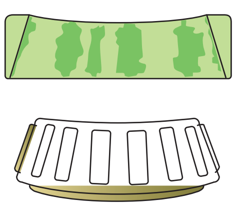
GALLING

Metal smears on roller ends due to overheating, lubricant failure, or overload. Replace bearing, check seals, and check for proper lubrication.



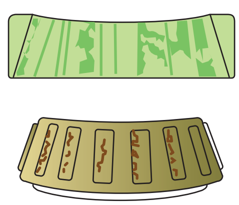
BENT CAGE

Cage damaged due to improper handling or tool usage. Replace bearing.



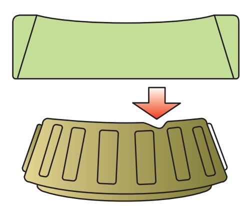
ABRASIVE ROLLER WEAR

Pattern on races and rollers caused by fine abrasives. Clean all parts and housings, check seals and bearings, and replace if leaking, rough, or noisy.



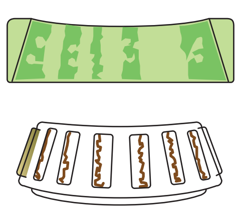
ETCHING

Bearing surfaces appear gray or grayish black in color with related etching away of material usually at roller spacing. Replace bearings, check seals, and check for proper lubrication.



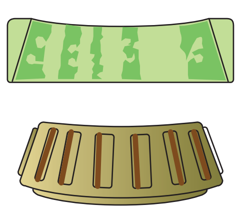
BENT CAGE

Cage damaged due to improper handling or tool usage. Replace bearing.



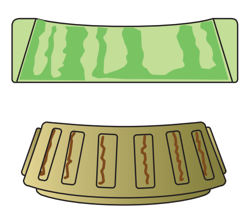
INDENTATIONS

Surface depressions on race and rollers caused by hard particles of foreign material. Clean all parts and housings. Check seals, and replace bearings if rough or noisy.



BRINELLING

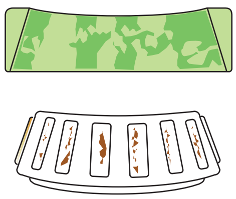
Surface indentations in raceway caused by rollers either under impact loading or vibration while the bearing is not rotating. Replace bearing if rough or noisy.



MISALIGNMENT

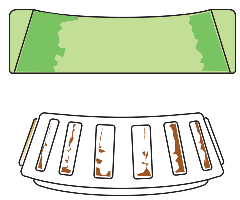
Outer race misalignment due to foreign object. Clean related parts and replace bearing. Make sure races are properly sealed.

***FIGURE 3-1* Bearing failures and corrective procedures.**



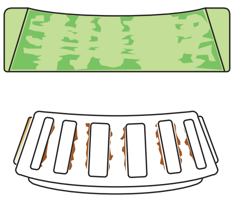
FATIGUE SPALLING

Flaking of surface metal resulting from fatigue. Replace bearing, clean all related parts.



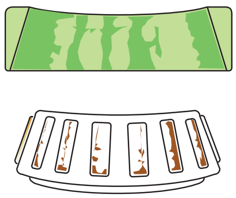
STAIN DISCOLORATION

Discoloration can range from light brown to black caused by incorrect lubricant or moisture. Re-use bearings if stains can be removed by light polishing or if no evidence of overheating is observed. Check seals and related parts for damage.



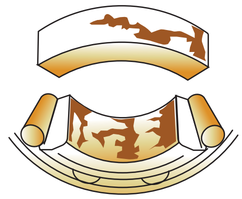
CAGE WEAR

Wear around outside diameter of cage and roller pockets caused by abrasive material and inefficient lubrication. Clean related parts and housings. Check seals and replace bearings.



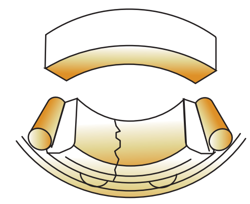
HEAT DISCOLORATION

Heat discoloration can range from faint yellow to dark blue, resulting from overload or incorrect lubricant. Excessive heat can cause softening of races or rollers. To check for loss of temper on races or rollers, a simple file test may be made. A file drawn over a tempered part will grab and cut metal, whereas, a file drawn over a hard part will glide readily with no metal cutting. Replace bearings if overheating damage is indicated. Check seals and other parts.



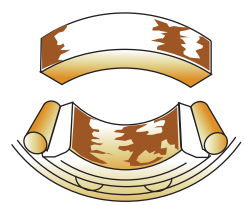
FRETTAGE

Corrosion set up by small relative movement of parts with no lubrication. Replace bearings. Clean related parts. Check seals and check for proper lubrication.



CRACKED INNER RACE

Race cracked due to improper fit, cocking, or poor bearing seats. Replace bearing and correct bearing seats.



SMEARS

Smearing of metal due to slippage. Slippage can be caused by poor fits, lubrication, overheating, overloads, or handling damage. Replace bearings, clean related parts, and check for proper fit and lubrication.

***FIGURE 3-2* Bearing failures and corrective procedures, continued.**

FIGURE 3-3 **Cleaning a bearing with solvent.**

FIGURE 3-4 **Wrapping a bearing in waterproof paper.**

Bearings may be placed in a tray and lowered into a container of clean solvent. A brush may be used to remove old grease from the bearing (Figure 3-3). The bearings may be dried with compressed air after the cleaning operation. Be sure the shop air supply is free from moisture, which causes rust formation in the bearing. After all the old grease has been cleaned from the bearing, rinse the bearing in clean solvent and dry it thoroughly with compressed air.

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When bearing cleaning is completed, bearings should be inspected for the defects illustrated in Figures 3-1 and 3-2. If any of these conditions are present on the bearing, replacement is necessary. Tapered roller bearings and their matching outer races must be replaced as a set. If the bearing installation is not done immediately, cover the bearings with a protective lubricant and wrap them in waterproof paper (Figure 3-4). Be sure to identify the bearings, or lay them in order, so you reinstall them in their original location. Do not clean bearings or races with paper towels. If you are using a shop towel for this purpose, be sure it is lint free. Lint from shop towels or paper towels may contaminate the bearing. Bearing races and the inner part of the wheel hub should be thoroughly cleaned with solvent and dried with compressed air. Inspect the seal mounting area in the hub for metal burrs. Remove any burrs with a fine round file.

The outer bearing race on a tapered roller bearing may be called a bearing cup.

Bearing races must be replaced if any of the defects described in Figures 3-1 and 3-2 are found. The proper bearing race driving tool must be used to remove the bearing races (Figure 3-5). If a driver is not available for the bearing races, a long brass punch and hammer may be used to drive the races from the hub. When a hammer and punch are used for this purpose, be careful not to damage the hub inner surface with the punch.

SPECIAL TOOLS
Bearing driver

The new bearing races should be installed in the hub with the correct bearing race driving tool (Figure 3-6). When bearings and races are replaced, be sure they are the same

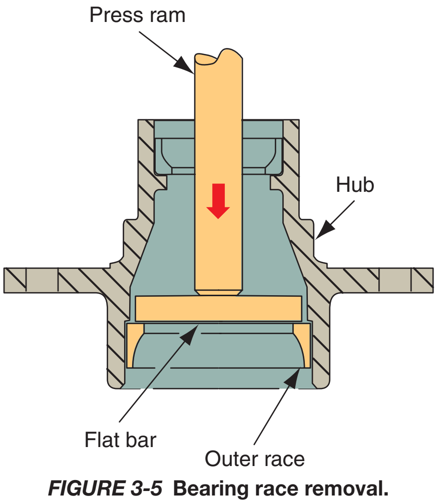

FIGURE 3-5 **Bearing race removal.**

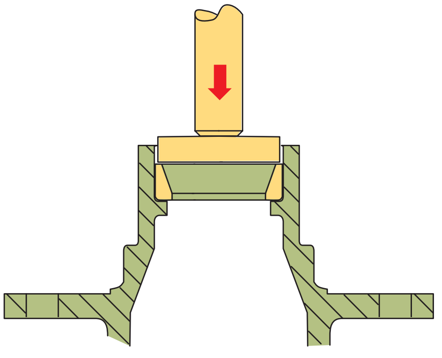

FIGURE 3-6 **Bearing race installation.**

Small dirt particles left behind the outer bearing race cause race misalignment and premature bearing failure.

CAUTION:
Cleanliness is very important during wheel bearing service. Always maintain cleanliness of hands, tools, work area, and all related bearing components. One small piece of dirt in a bearing will cause bearing failure.

CAUTION:
Always keep grease containers covered when not in use. Uncovered grease containers are easily contaminated with dirt and moisture.

as the original bearings. The part numbers should be the same on the old bearings and the replacement bearings.

Inspect the bearing and seal mounting surfaces on the spindle. Small metal burrs may be removed from the spindle with a fine-toothed file. If the spindle is severely scored in the bearing or seal mounting areas, spindle replacement is necessary.

Bearing Lubrication and Assembly

After the bearings and races have been cleaned and inspected, the bearings should be packed with grease. Always use the vehicle manufacturer's specified wheel bearing grease. Vehicle manufacturers usually recommend a lithium-based wheel bearing grease. Place a lump of grease in the palm of one hand and grasp the bearing in the other hand. Force the widest edge of the bearing into the lump of grease, and squeeze the grease into the bearing. Continue this process until grease is forced into the bearing around the entire bearing circumference. Place a coating of grease around the outside of the rollers, and apply a light coating of grease to the races. A bearing packing tool may be used to force grease into the bearings rather than using the hand method. Bearing packers may be hand operated or pressure operated (Figure 3-7).

Place some grease in the wheel hub cavity and position the inner bearing in the hub (Figure 3-8). Check the fit of the new bearing seal on the spindle and in the hub. The seal lip must fit snugly on the spindle, and the seal case must fit properly in the hub opening. The part number on the old seal and the replacement seal should be the same. Be sure the seal is installed in the proper direction with the garter spring and higher part of the lip toward the lubricant in the hub. The new inner bearing seal must be installed in the hub with a suitable seal driver (Figure 3-9). Place a light coating of wheel bearing grease on the spindle and slide the hub assembly onto the spindle. Install the outer wheel bearing and be sure there is adequate lubrication on the bearing and race. Be sure the washer and nut are clean and install these components on the spindle (Figure 3-10). Tighten the nut until it is finger tight.

Photo Sequence 3 shows a typical procedure for adjusting rear wheel bearings on a front-wheel-drive car.

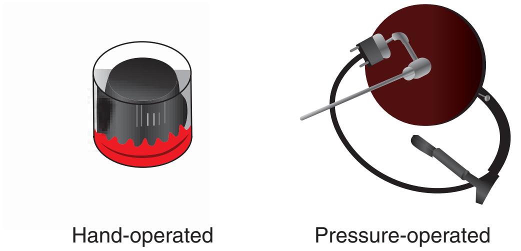

FIGURE 3-7 **Mechanical wheel bearing packer.**

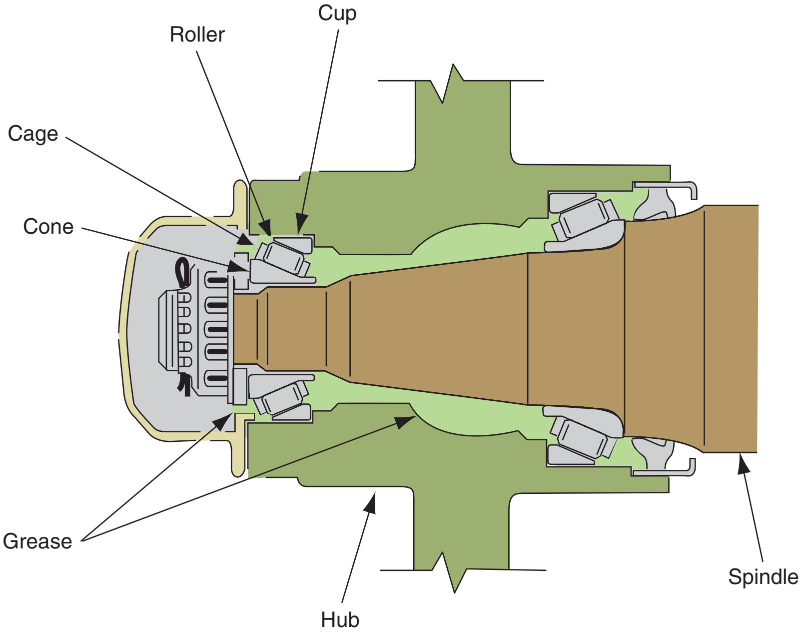

FIGURE 3-8 **Wheel bearing lubrication.**

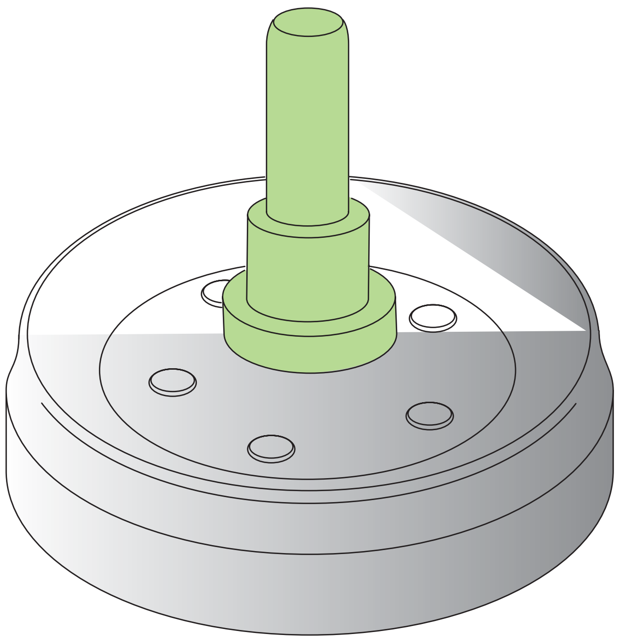

FIGURE 3-9 **Seal installation.**

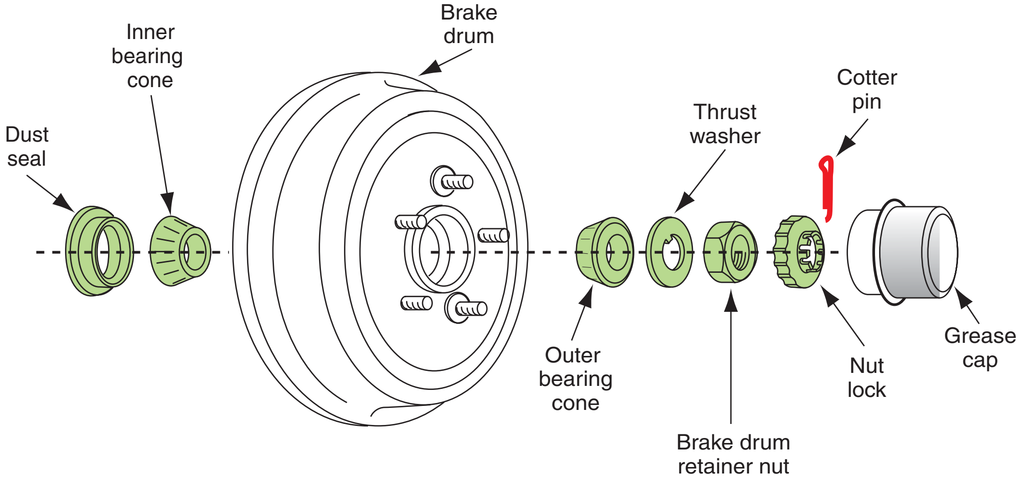

FIGURE 3-10 **Installation of wheel bearings and related components.**

SERVICE TIP: When a lip seal is installed, the garter spring should always face toward the flow of lubricant.

Wheel Bearing Adjustment with Two Separate Tapered Roller Bearings in the Wheel Hub

Wheel bearing endplay is the amount of horizontal wheel bearing hub movement. If a bearing has a preload condition, a slight tension is placed on the bearing. Loose front wheel bearing adjustment results in lateral front wheel movement and reduced directional stability. If the

SPECIAL TOOLS
Seal driver

CUSTOMER CARE: Never sell a customer automotive service that is not required on his or her car. Selling preventive maintenance, however, is a sound business practice and may save a customer some future problems. An example of preventive maintenance is selling a cooling system flush when the cooling system is not leaking but the manufacturer's recommended service interval has elapsed. If customers find out they were sold some unnecessary service, they will probably never return to the shop. They will likely tell their friends about their experience, and that kind of advertising the shop can do without.

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PHOTO SEQUENCE 3

Typical Procedure for Adjusting Rear Wheel Bearings on a Front-Wheel-Drive Car

P3-1 **Always make sure the car is positioned safely on a lift before working on the vehicle.**

P3-2 **Remove the dust cap from the wheel hub.**

P3-3 **Remove the cotter pin and nut retainer from the bearing adjusting nut.**

P3-4 **Tighten the bearing adjusting nut to 17 to 25 ft-lb.**

P3-5 **Loosen the bearing adjusting nut one-half turn.**

P3-6 **Tighten the bearing adjusting nut to 10 to 15 in-lb.**

P3-7 **Position the adjusting nut retainer over the adjusting nut so the slots are aligned with the holes in the nut and spindle.**

P3-8 **Install a new cotter pin and bend the ends around the retainer flange.**

P3-9 **Install the dust cap and be sure the hub rotates freely.**

wheel bearing adjusting nut is tightened excessively, the bearings may overheat, resulting in premature bearing failure. The bearing adjustment procedure may vary depending on the make of vehicle. Always follow the procedure in the vehicle manufacturer's service manual.

A typical bearing adjustment procedure follows:

1. With the hub and bearings assembled on the spindle, tighten the adjusting nut to 17 to 25 ft-lb. (23 to 34 Nm) while the hub is rotated in the forward direction.
2. Loosen the adjusting nut 1/2 turn and retighten it to 10 to 15 in-lb. (1.0 to 1.7 Nm). This specification varies depending on the make of vehicle. Always use the manufacturer's specifications.
3. Position the adjusting nut retainer over the nut so the retainer slots are aligned with the cotter pin hole in the spindle.
4. Install a new cotter pin, and bend the ends around the retainer flange.
5. Install the grease cap, and make sure the hub and drum rotate freely.

After a wheel bearing adjustment is performed, the hub must have an endplay of 0.001 in. to 0.005 in. (0.0254 mm to 0.127 mm). A dial indicator may be mounted with the stem positioned against the outer edge of the hub to perform this measurement. When the hub is pulled outward and pushed inward, the specified endplay must be displayed on the dial indicator. If the endplay is not correct, the wheel bearing adjustment must be repeated.

Wheel Hub Unit Diagnosis

When wheel bearings and hubs are an integral assembly, the bearing endplay should be measured with a dial indicator stem mounted against the hub. If the endplay exceeds 0.005 in. (0.127 mm) as the hub is moved in and out, the hub and bearing assembly should be replaced. This specification is typical, but the vehicle manufacturer's specifications must be used. Hub and bearing replacement is also necessary if the bearing is rough or noisy. Integral-type bearing and hub assemblies are used on the front and rear wheels on some front-wheel-drive cars. Photo Sequence 4 shows a typical procedure for measuring front wheel hub endplay.

SPECIAL TOOLS
Dial indicator

When removable front wheel bearings are mounted in the steering knuckle, the wheel bearings may be checked with the vehicle raised on the hoist and a dial indicator positioned against the outer wheel rim lip as shown in Figure 3-11.

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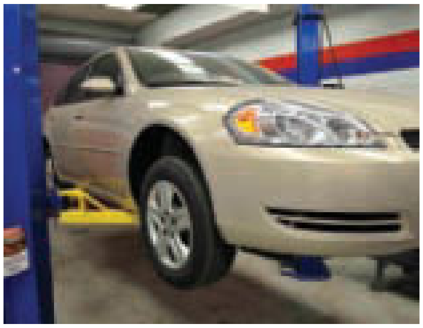
When the wheel is moved in and out, the maximum bearing movement on the dial indicator should be as follows:

0.020 in. (0.508 mm) for 13-in. (33-cm) wheels
0.023 in. (0.584 mm) for 14-in. (35.5-cm) wheels
0.025 in. (0.635 mm) for 15-in. (38-cm) wheels

FIGURE 3-11 **Wheel bearing diagnosis on vehicle.**

PHOTO SEQUENCE 4

Typical Procedure for Measuring Front Wheel Hub Endplay—Integral, Sealed Wheel Bearing Hub Assemblies



P4-1 **Be sure the vehicle is properly positioned on a lift before the wheel bearing hub endplay measurement is performed. The vehicle should be properly positioned on a lift with the lift raised to a comfortable working height for performing this measurement.**

P4-2 **Remove the wheel cover and dust cap.**

P4-3 **Attach a magnetic dial indicator base securely to the inside of the fender at the lower edge of the wheel opening. Position the dial indicator stem against the vertical wheel surface as close as possible to the top wheel stud, and preload the dial indicator stem.**

P4-4 **Zero the dial indicator pointer.**

P4-5 **Grasp the top of the tire with both hands. Push and pull on the top of the tire without rotating the tire, and note the dial indicator readings with the tire pushed inward and the tire pulled outward. The difference between the two readings is the wheel hub endplay. Repeat this procedure twice to verify the endplay reading.**

P4-6 **Maximum wheel bearing endplay should be 0.005 in. (0.127 mm). If the endplay measurement is not correct, wheel bearing hub replacement is necessary.**

P4-7 **Remove the dial indicator and install the dust cap and wheel cover.**

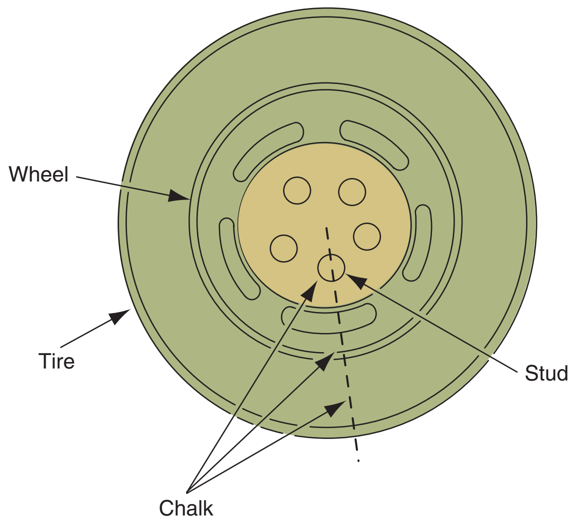


FIGURE 3-12 **Chalk marking on wheel, tire, and stud.**

If the bearing movement is excessive, check the hub nut torque before replacing the bearing. When this torque is correct and bearing movement is excessive, the bearing should be replaced.

When a wheel is removed to service the wheel bearings, proper balance must be maintained between the wheel and tire and the hub. Therefore, the tire, wheel, and hub stud should be chalk marked prior to removal (Figure 3-12).

Front Drive Axle Diagnosis

On many front-wheel-drive vehicles, the front drive axles must be removed before the wheel hub unit or steering knuckle and bearing can be detached. Therefore, we will discuss front drive axle diagnosis and removal. Because drive axle noises may be confused with front wheel bearing noise, a brief discussion of drive axle noises and problems may be helpful. A defective inner drive axle joint usually causes a vibration when the vehicle is decelerating at 35 to 45 miles per hour (mph), or 56 to 72 kilometers per hour (km/h). A worn inner drive axle joint may also cause vibration during acceleration. When an outer drive axle joint is worn, a clicking noise is heard during a hard turn below 20 mph (32 km/h). To determine which drive axle has the defective joint, lift the vehicle on a hoist, and allow the front wheels to drop down. This action will position the axle joints at a different angle than when the car is driven on the road. Lift the lower control arms one at a time with a floor jack, and place the transmission in drive to simulate the driving conditions that provided the vibration or noise. If the vibration or noise occurs with one lower control arm lifted, that side has the defective drive axle joint.

Drive Axle Removal

Many drive axles have a **circlip** on the inner joint extension that holds the inner joint into the differential side gear. Drive axle systems vary depending on the vehicle. Follow the drive axle removal procedure in the vehicle manufacturer's service manual.

A **circlip** is a split, circular clip mounted in a groove on the inner drive axle joint extension to retain the drive axle in the transaxle on some front-wheel-drive-vehicles.

A general front drive axle removal procedure follows:

1. Loosen the front wheel nuts and hub nuts.
2. Lift the vehicle on a hoist and be sure the hoist safety mechanism is in place; then remove the front wheels and tires.
3. Remove the brake calipers and rotors. Connect a piece of wire from the calipers to a suspension or chassis component. Do not allow the calipers to hang on the end of the brake line.
4. Install protective drive axle boots if these are supplied by the car manufacturer.
5. Remove the ball joint to steering knuckle clamp bolt (Figure 3-13).

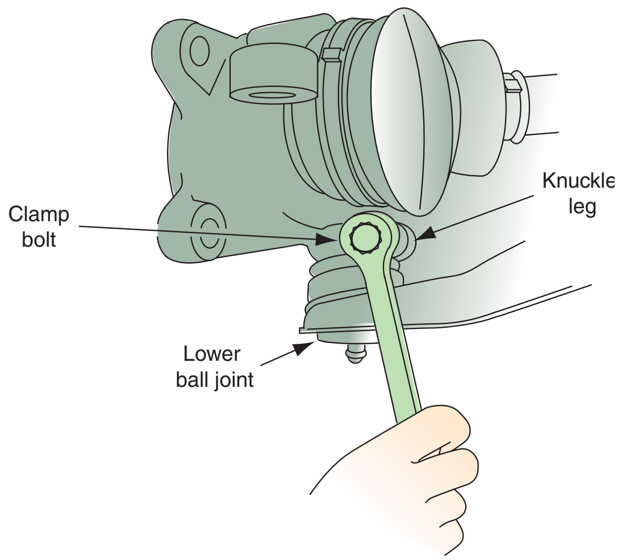


FIGURE 3-13 **Removal of ball joint to steering knuckle clamp bolt.**

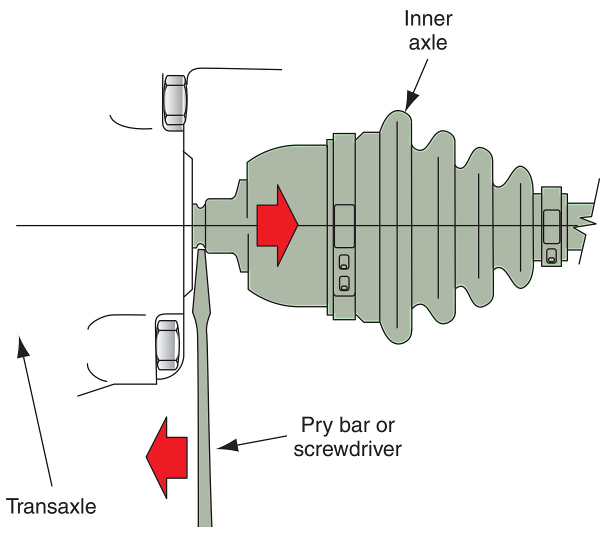


FIGURE 3-14 **Removal of inner axle joint from transaxle.**

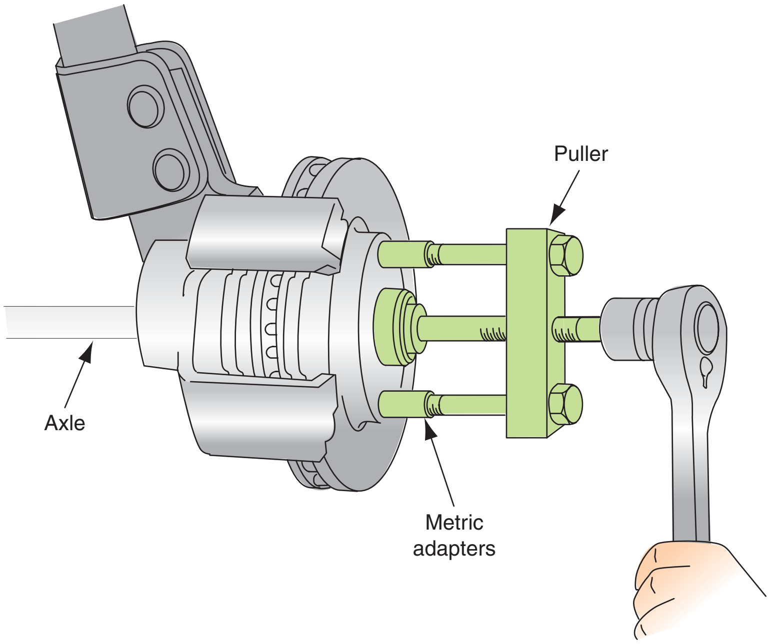


FIGURE 3-15 **Removal of outer axle joint from front wheel hub.**

6. Pry the ball joint stud from the steering knuckle.
7. Pull the inner axle from the transaxle (Figure 3-14); do not allow the axle to drop down at a severe angle.
8. Remove the hub nut and washer, and separate the outer axle joint from the wheel hub. Some outer axle joint splines are slightly spiraled. On this type of outer axle joint, a special puller is required to separate the axle joint from the wheel (Figure 3-15).
9. Remove the drive axle from the chassis.

SPECIAL TOOLS

Front wheel bearing hub pulling and installing tools

Reverse the drive axle removal procedure for front drive axle installation.

Special Procedures for Drive Axle Removal

Some car manufacturers recommend removal of the strut from the steering knuckle rather than removal of the ball joint when the drive axles are removed. This type of suspension system has a threaded nut on the ball joint stem to hold the ball joint into the steering knuckle. If an

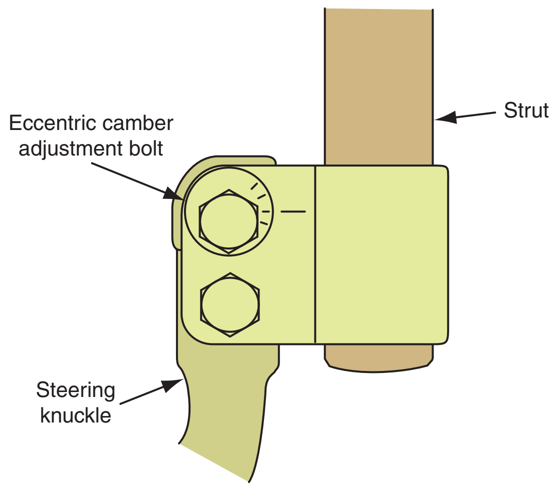


FIGURE 3-16 **Marking eccentric strut bolt before removal.**

eccentric camber adjustment bolt is positioned in the strut, the bolt head position should be marked in relation to the strut before the bolt is removed (Figure 3-16).

On these suspension systems, the brake calipers and brake line clamps should be removed before the drive axles. Some car manufacturers supply a slide-hammer-type puller to remove the inner axle joints from the transaxle.

On Chrysler manual and automatic transaxles, the speedometer gear must be removed from the right differential extension housing before the right drive axle is removed (Figure 3-17).

Early model Chrysler transaxles had circlip retainers, which held the inner drive axle joints into the differential side gears. The differential cover had to be removed and these circlips had to be compressed with needle nose pliers before the drive axles could be removed from the differential side gears. The drive axles had to be rotated until a flat area on the axle and the circlip ends were visible (Figure 3-18).

The inner joint housings did not have tripod springs on early models. Later model Chrysler drive axles may be pulled from the differential side gears without collapsing the

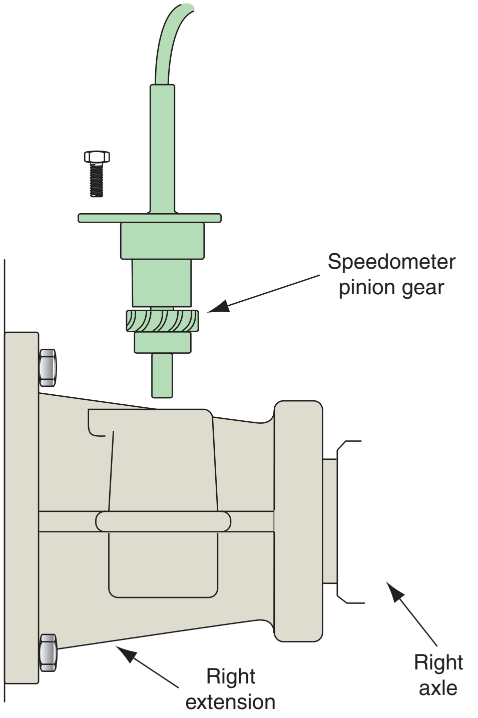


FIGURE 3-17 **Speedometer drive gear removal before right axle removal.**

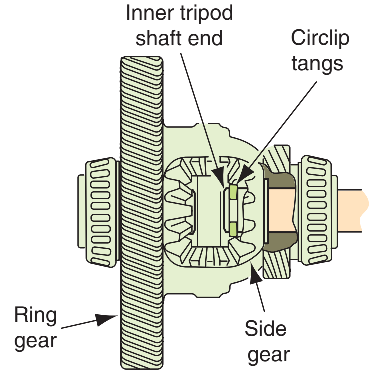


FIGURE 3-18 **Compressible circlips in early model Chrysler transaxles.**

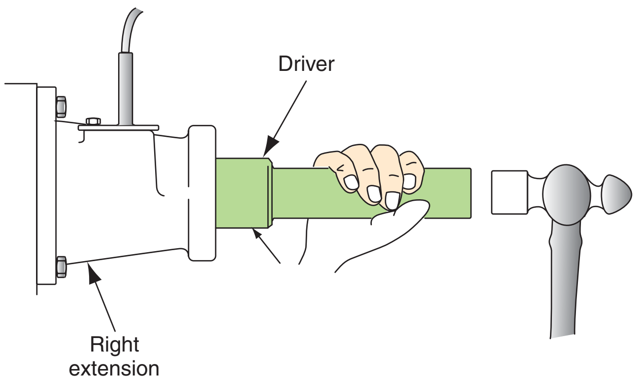


FIGURE 3-19 **Removal of left inner drive axle joint on Ford automatic transaxles.**

circlips. To determine which type of circlip is used, grasp the inner joint housing and try to pull it out of the transaxle. If the inner joint housing moves outward and springs back into the transaxle, the joint has a later model circlip. When the inner joint is solid in the transaxle, the older model circlip, which requires compressing before removal, is used.

On Ford automatic transaxles (ATX), the left inner axle joint is inset into the transaxle housing. In this location, it is impossible to pry the axle joint from the transaxle. Therefore, the right axle joint must be removed first. A special tool is then used to drive the left inner axle joint from the differential side gear (Figure 3-19).

If both left and right drive axles are removed at the same time on Ford transaxles, the differential side gears may become dislocated. When this occurs, the differential must be removed to realign the side gears. The special tool for driving out the left inner axle joint may be left in place to support the side gears on ATX models. On manual transaxles (MTX), shipping plugs T81P-1177-B should be installed in each side gear when the drive axles are removed.

SERVICE TIP:
Do not remove the tool until the left inner axle joint is reinstalled in the Ford ATX. If the tool is removed without installing the left inner axle joint, the side gears may fall out of place. If this action occurs, the Ford ATX may have to be disassembled to install the side gears properly.

Front Wheel Bearing Hub Unit Removal and Replacement

The front wheel bearing removal and replacement procedure varies depending on the vehicle and the type of front wheel bearing. Always follow the front wheel bearing removal and replacement procedure in the manufacturer's service manual. The following procedure applies to front wheel bearing units that are pressed into the steering knuckle.

When front wheel bearing replacement is necessary, the steering knuckle must be removed and the wheel hub must be pressed from the bearing with a special tool (Figure 3-20).

A special puller is used to remove and replace the wheel bearing in the knuckle (Figures 3-21 and 3-22).

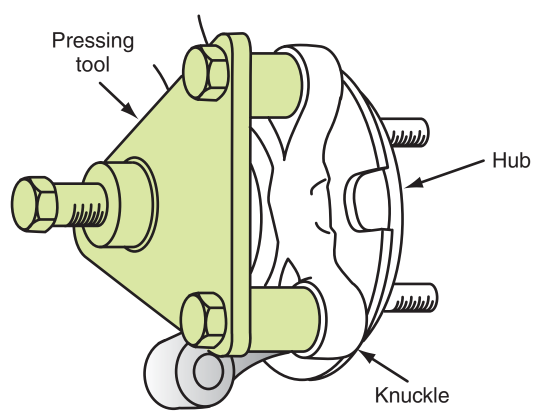


FIGURE 3-20 **Wheel hub removal from bearing.**

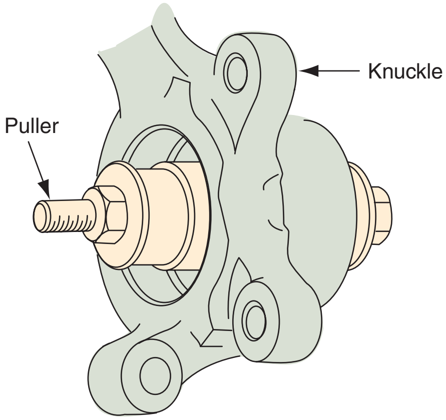


FIGURE 3-21 **Wheel bearing removal from knuckle.**

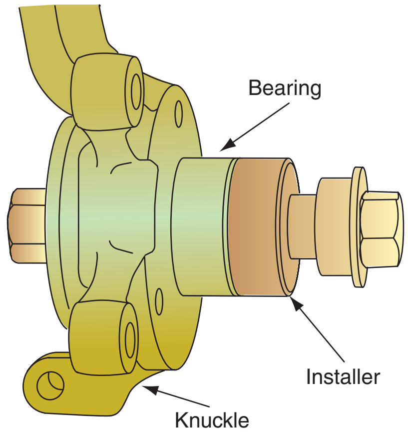


FIGURE 3-22 **Wheel bearing installation in knuckle.**

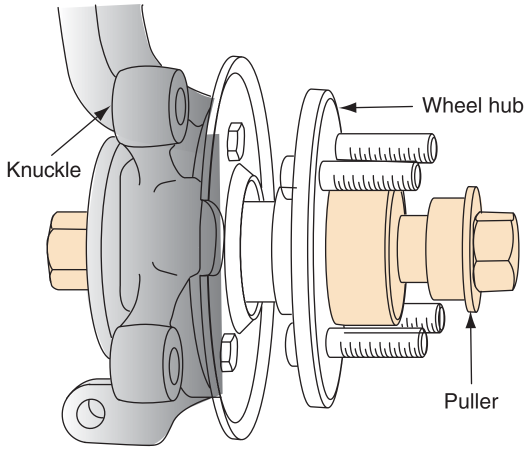


FIGURE 3-23 **Wheel hub installation in wheel bearing.**

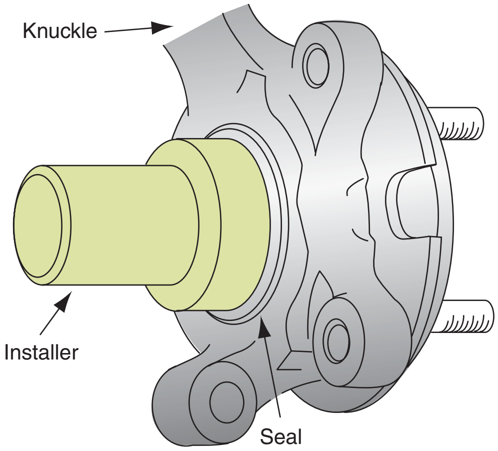


FIGURE 3-24 **Seal installation in steering knuckle.**

The wheel hub must be pulled into the wheel bearing with a special tool (Figure 3-23). The proper driving tool is used to install the seal behind the bearing in the knuckle (Figure 3-24).

When two separate roller bearings are mounted in the steering knuckle, the bearing races must be driven from the knuckle with a hammer and punch. These bearings must be lubricated with wheel bearing grease prior to installation, as described earlier in this chapter. When the wheel bearings are removed, all wheel bearing seals must be replaced. A staked-type hub nut must be replaced if it is removed.

On these front-wheel-drive cars, the hub nut torque applies the correct adjustment on the front wheel bearings. Therefore, this torque is extremely important. With the brakes applied, the hub nut should be tightened to the specified torque (Figure 3-25). When the hub nut is torqued to specifications, the nut lock and cotter pin should be installed (Figure 3-26).

CAUTION: Never use an impact wrench to tighten a hub nut. This action may cause wheel bearing damage.

WARNING: Never reuse a cotter pin. A used cotter pin may break, allowing the hub nut to loosen. This may allow the wheel and hub to come off.

After the wheel is installed, the wheel nuts should be tightened in sequence to the specified torque (Figure 3-27). On cars with the front wheel bearings mounted in the steering knuckles, never move a car unless the front hub nuts are torqued to specifications. Lack of bearing preload could damage the bearings if the hub nuts are not tightened to specifications. If the car must be moved when the drive axles are removed, place a large bolt and nut with suitable washers through the front wheel bearing and tighten the nut to specifications.

FIGURE 3-25 **Hub nut torquing.**

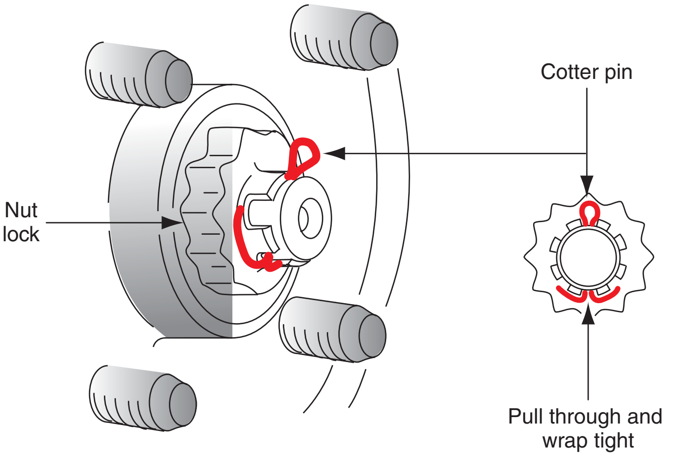


FIGURE 3-26 **Nut lock and cotter pin installation.**

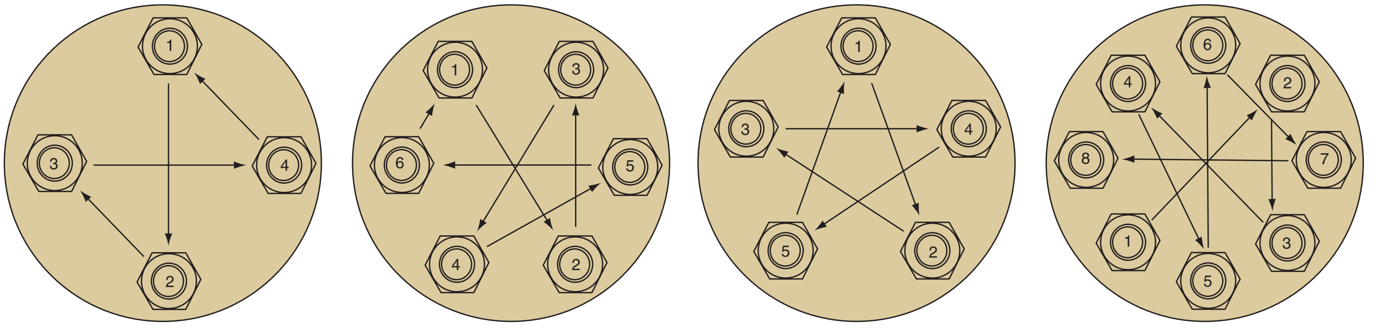


FIGURE 3-27 **Wheel nut tightening sequence.**

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Rear-Axle Bearing and Seal Service, Rear-Wheel-Drive Cars

WARNING: Use extreme caution when diagnosing problems with a vehicle raised on a hoist and the engine running with the transmission in drive. Keep away from rotating wheels, drive shafts, or drive axles.

SPECIAL TOOLS
Technician's stethoscope

"C" locks are split, circular, metal rings that fit in rear axle grooves to retain the rear axles in the differential on some rear-wheel-drive vehicles.

Rear-axle bearing noise may be diagnosed with the vehicle raised on a hoist. Be sure the hoist safety mechanism is engaged after the vehicle is raised on the hoist. With the engine running and the transmission in drive, operate the vehicle at a moderate speed of 35 to 45 mph (56 to 72 km/h) and listen with a **stethoscope** placed on the rear axle housing directly over the axle bearings. If grinding or clicking noises are heard, the bearing must be replaced.

Many axle shafts in rear-wheel-drive cars have a roller bearing and seal at the outer end (Figure 3-28). These axle shafts are often retained in the differential with **"C" locks** that must be removed before the axles.

The rear-axle bearing removal and replacement procedure varies depending on the vehicle make and model year. Always follow the rear-axle bearing removal and replacement procedure in the manufacturer's service manual.

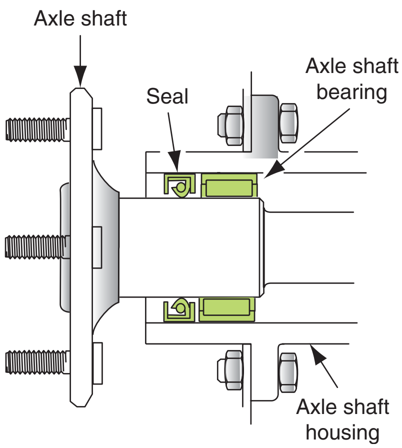

FIGURE 3-28 **Rear axle roller bearing and seal, rear-wheel-drive car.**

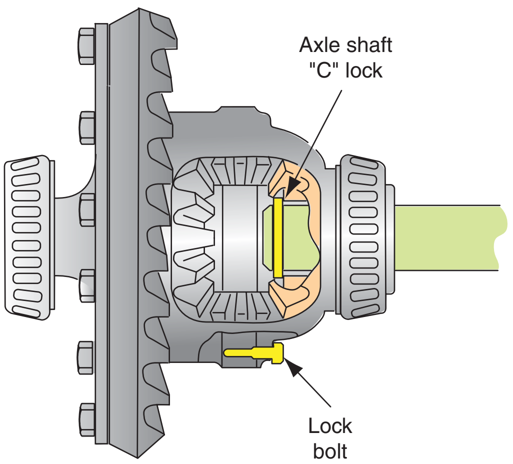

FIGURE 3-29 **Rear axle "C" lock, lock bolt, and pinion gears.**

A typical rear axle shaft removal and replacement procedure on a rear-wheel-drive car with "C" lock axle retainers is as follows:

1. Loosen the rear wheel nuts and chalk mark the rear wheel position in relation to the rear axle studs.
2. Raise the vehicle on a hoist and make sure the hoist safety mechanism is in place.
3. Remove the rear wheels and brake drums, or calipers and rotors.
4. Place a drain pan under the differential and remove the differential cover. Discard the old lubricant.
5. Remove the differential lock bolt, pin, pinion gears, and shaft (Figure 3-29).
6. Push the axle shaft inward and remove the axle "C" lock.
7. Pull the axle from the differential housing.

Reverse the axle removal procedure to reinstall the axle. Always use a new differential cover gasket, and fill the differential to the bottom of the filler plug opening with the manufacturer's recommended lubricant. Be sure all fasteners, including the wheel nuts, are tightened to the specified torque.

SPECIAL TOOLS
Seal puller
Bearing puller

A typical axle bearing and seal removal procedure follows:

1. Remove the axle seal with a seal puller.
2. Use the proper bearing puller to remove the axle bearing (Figure 3-30).

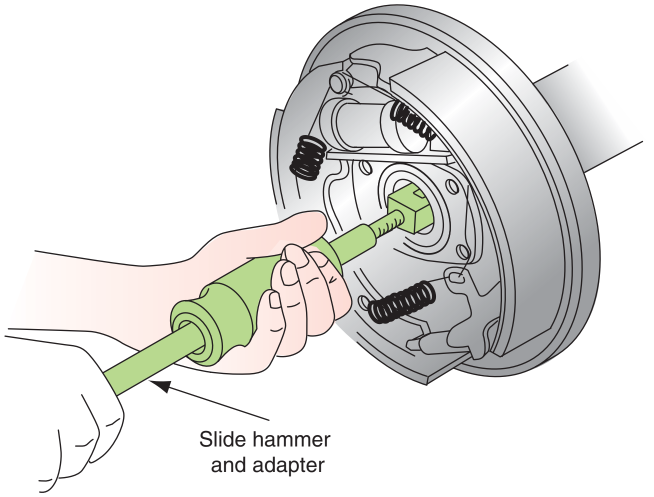

FIGURE 3-30 **Rear-axle bearing puller.**

3. Clean the axle housing seal and bearing mounting area with solvent and a brush. Clean this area with compressed air.
4. Check the seal and bearing mounting area in the housing for metal burrs and scratches. Remove any burrs or irregularities with a fine-toothed round file.
5. Wash the axle shaft with solvent and blow it dry with compressed air.
6. Check the bearing contact area on the axle for roughness, pits, and scratches. If any of these conditions are present, the axle must be replaced.
7. Be sure the new bearing fits properly on the axle and in the housing. Install the new bearing with the proper bearing driver (Figure 3-31). The bearing driver must apply pressure to the outer race that is pressed into the housing.
8. Be sure the new seal fits properly on the axle shaft and in the housing. Make sure the garter spring on the seal faces toward the differential. Use the proper seal driver to install the new seal in the housing (Figure 3-32).
9. Lubricate the bearing, seal, and bearing surface on the axle with the manufacturer's specified differential lubricant.
10. Reverse the rear axle removal procedure to reinstall the rear axle.
11. Be sure all fasteners are tightened to the specified torque.

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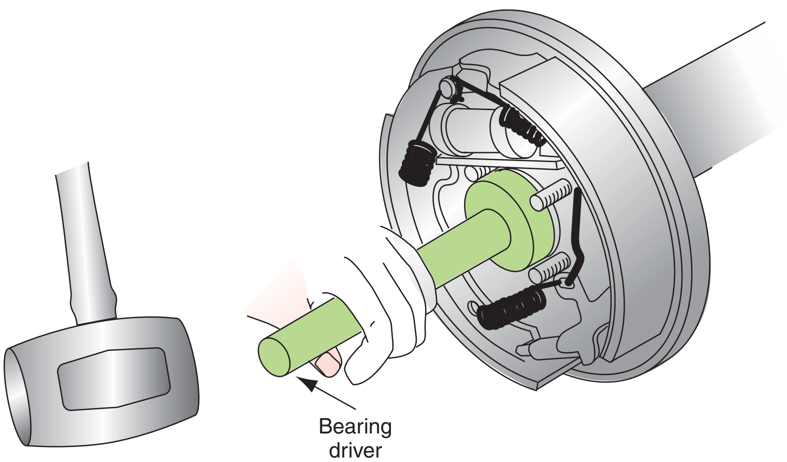

FIGURE 3-31 **Rear-axle bearing driver.**

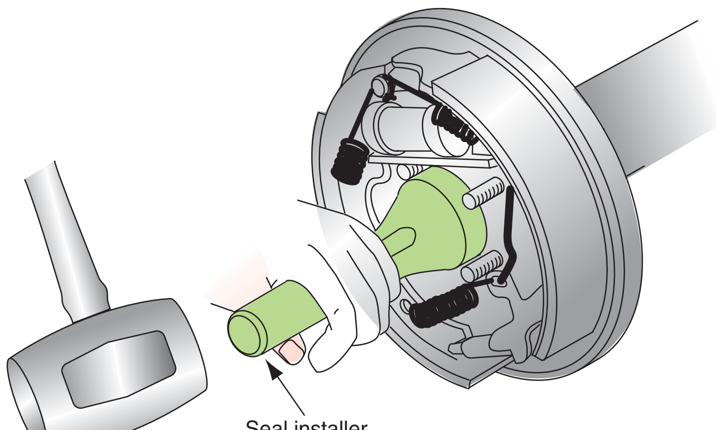

FIGURE 3-32 **Installing rear axle seal.**

WARNING: Never use an acetylene torch to heat axle bearings or adaptor rings during the removal and replacement procedure. The heat may cause fatigue in the steel axle and the axle may break suddenly, causing the rear wheel to fall off. This action will likely result in severe vehicle damage and personal injury.

SPECIAL TOOLS
Axle puller

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Some rear axles have a sealed bearing that is pressed onto the axle shaft and held in place with a retainer ring. These rear axles usually do not have "C" locks in the differential. A retainer plate is mounted on the axle between the bearing and the outer end of the axle. This plate is bolted to the outer end of the differential housing. After the axle retainer plate bolts are removed, a slide-hammer-type puller is attached to the axle studs to remove this type of axle. When this type of axle bearing is removed, the adaptor ring must be split with a hammer and chisel while the axle is held in a vise. Do not heat the adaptor ring or the bearing with an acetylene torch during the removal or installation process. After the adaptor ring is removed, the bearing must be pressed from the axle shaft, and the bearing must not be reused. A new bearing and adaptor ring must be pressed onto the axle shaft. The bearing removal and replacement procedure is shown in Figure 3-33.

DIAGNOSTIC TABLE

Problem	Symptoms	Possible causes
Noise in drive train, front-wheel-drive car.	Clicking noise while turning a corner at low speeds.	Worn outer front drive axle joint.
Vibration in front drive train, front-wheel-drive car.	Vibration while decelerating at 35 to 45 mph, 56 to 72 km/h.	Worn inner drive axle joint.
Noise in front suspension.	Growling noise in front suspension, most noticeable when turning a corneror driving at low speeds.	Worn wheel bearings.
Lack of directional stability.	Steering wanders to either side when driving straight ahead.	Excessive front wheel bearing endplay, improper wheel bearing adjustment.
Noise in drive train, rear-wheel-drive car.	Constant growling or clicking noise in rear axle, most noticeable when driving at low speeds or down a narrow street.	Worn rear-axle bearing.

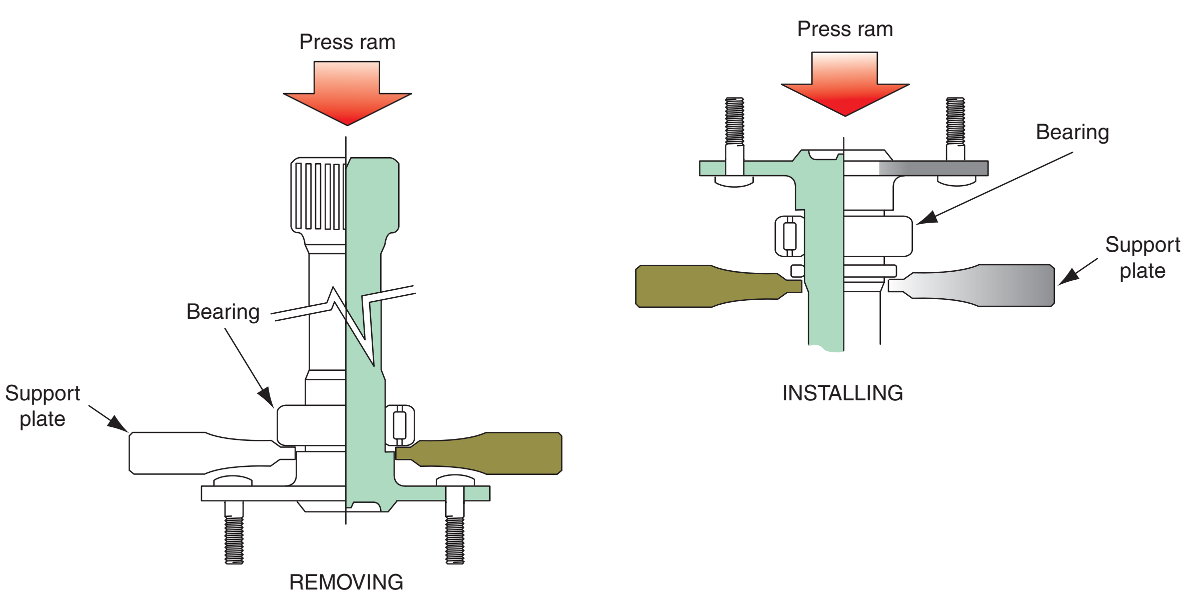

FIGURE 3-33 **Axle bearing and adaptor ring removal and replacement.**

Terms to Know

Bearing brinelling
Bearing fatigue spalling
Bearing frettage
Bearing indentations
Bearing smears
Circlip
"C" locks
Stethoscope

CASE STUDY

A customer complains of a bearing noise in the right front wheel of his Lincoln Town Car. He says the right front outer wheel bearing has been replaced twice in the last year, and this is the third failure. The technician asks the customer about the mileage intervals between bearing replacements, and the customer indicates that the wheel bearing has lasted about 8,000 miles (12,800 kilometers) each time it has been replaced. The technician finds out from the customer that no other work was done on the car each time the bearing was replaced.

When the technician removes the right front wheel and hub, the outer bearing rollers and races are badly scored. After cleaning both bearings, races, and hub, the technician closely examines the outer bearing race. It shows an uneven wear pattern, which indicates misalignment. The technician removes the outer bearing race and finds a small metal burr behind the bearing race. This burr caused race misalignment and excessive wear on the race and rollers. The technician removes the burr with a fine-toothed file. The inner bearing and race have indentation wear because metal particles from the outer bearing contaminated the lubricant in the hub. The technician removes the inner bearing race and cleans the hub and spindle thoroughly. He replaces both bearings and the inner seal and repacks the bearings and hub with grease. After reinstalling the hub, the technician carefully adjusts the bearings to the manufacturer's specifications and tightens the wheel nuts to the specified torque. A road test indicates that the bearing noise has been eliminated.

One small metal burr caused this customer a considerable amount of unnecessary expense. This experience proves that a technician's diagnostic capability is extremely important!

ASE-Style Review Questions

1. While discussing defective bearings:
   Technician A says brinelling appears as indentations across the bearing races.
   Technician B says brinelling occurs while the bearing is rotating.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While discussing bearing defects:
   Technician A says misalignment wear on a front wheel bearing could be caused by a metal burr behind one of the bearing races.
   Technician B says misalignment wear on a front wheel bearing could be caused by a bent front spindle.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. While discussing front wheel bearing service on a vehicle with the bearing hub unit pressed into the steering knuckle:
   Technician A says the front wheel bearings may be damaged if this front-wheel-drive vehicle is moved without the hub nuts torqued to specifications.
   Technician B says the hub nut torque supplies the correct wheel bearing adjustment.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. While discussing front wheel bearing service on a front-wheel-drive car with two separate tapered roller bearings mounted in the front steering knuckles:

   Technician A says the hub nut torque supplies the correct bearing adjustment.

   Technician B says that the brake should be applied while the front hub nuts are torqued.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

5. A front-wheel-drive vehicle has 14-in (35.5-cm) rims and front wheel bearings mounted in the steering knuckles. The vehicle is lifted on a hoist, and a dial indicator is positioned against the outer rim lip. The total inward and outward rim movement is 0.035 in (0.889 mm).

   Technician A says that the wheel bearing may require replacement.

   Technician B says that the hub nut torque should be checked prior to bearing replacement.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

6. When cleaning and inspecting wheel bearings:

   A. Sealed bearings should be washed in solvent.
   B. High-pressure air may be used to spin the bearings.
   C. A bent bearing cage may be caused by improper tool use.
   D. Bearing overload may cause bearing cage wear.

7. All these statements about hub seal service are true EXCEPT:

   A. The garter spring must face toward the flow of lubricant.
   B. A ball peen hammer should be used to install the seal.
   C. Seal contact area on the spindle must be clean and free from metal burrs.
   D. The outer edge of the seal case should be coated with sealant.

8. When servicing press-in rear-axle bearings on a rear-wheel-drive car:

   A. These bearing may be reused after they are removed from the axle shaft.
   B. The bearing adaptor ring should be removed by splitting it with a hammer and chisel.
   C. A cutting torch may be used to cut the bearing off the axle shaft.
   D. An acetylene torch may be used to heat the new adaptor ring prior to installation.

9. A front-wheel-drive vehicle has two tapered roller bearings in each rear wheel hub. When adjusting these wheel bearings:

   A. The adjusting nut should be tightened to 17 to 25 ft-lb (23 to 24 Nm), backed off 1/2 turn, and then tightened to 10 to 15 in-lb (1.0 to 1.7 Nm).
   B. The adjusting nut should be tightened to 40 ft-lb (54 Nm), backed off 1 turn, and then tightened to 10 ft-lb (13.5 Nm).
   C. The adjusting nut should be tightened to 50 ft-lb (67.5 Nm), backed off 3/4 turn, and then tightened to 10 to 15 in-lb (1.0 to 1.7 Nm).
   D. The wheel and hub should not be rotated while adjusting the wheel bearings.

10. A unitized front wheel bearing hub that is bolted to the steering knuckle has 0.010 in (0.254 mm) of hub endplay. The proper repair procedure is to:

    A. Repack and readjust the wheel bearings in the hub.
    B. Tighten the hub nut to the specified torque.
    C. Inspect the drive axle and hub splines, and replace the worn components.
    D. Replace the wheel bearing hub assembly.

ASE Challenge Questions

1. The customer says her front-wheel-drive car makes "a moaning noise" in a turn. Which of the following could cause this problem?
   A. Outer front wheel bearing.
   B. Rear-axle bearing.
   C. Differential gear noise.
   D. Transaxle output shaft bearing.
2. The customer complains of a "whining noise" in the back of her rear-wheel-drive car when driving between 30 and 40 miles per hour.
   Technician A says a good way to diagnose this problem is on a hoist with a stethoscope.
   Technician B says a good way to diagnose this problem is on the road with a microphone.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
3. Upon inspecting a noisy front wheel bearing from a 4WD sport utility vehicle, brinelling damage to the outer bearing race was noticed.
   Technician A says the damage was probably caused by tightening the bearing nut with an impact wrench.
   Technician B says the damage was probably caused by driving the vehicle through deep, muddy water.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
4. While discussing the cause of overheating damage of a front wheel bearing:
   Technician A says overheating may be caused by insufficient or incorrect bearing lubricant.
   Technician B says overheating may be caused by overtightening the wheel bearing nut on installation.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
5. The customer says her front-wheel-drive car has a noise and vibration when decelerating and is most noticeable under 50 miles per hour. Which would be the most probable cause of this problem?
   A. Defective outer front wheel bearing.
   B. Defective inner front wheel bearing.
   C. Defective outer drive axle joint.
   D. Defective inner drive axle joint.

Name ______________________________ Date ____________________

Service Integral Wheel Bearing Hubs

Upon completion of this job sheet, you should be able to measure integral wheel bearing hub endplay, and remove and replace integral wheel bearing hubs.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task D-2: Remove, inspect, and service or replace front and rear wheel bearings.

Tools and Materials

A front-wheel-drive vehicle with integral-type front wheel bearing hubs

A floor jack and safety stands, or a lift for raising the vehicle

Dial indicator

Integral wheel bearing hub puller

Torque wrench

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ______________________

VIN ______________________________ Engine type and size ____________________

Procedure

Task Completed

1. Road test the vehicle and listen for any abnormal wheel bearing noises; check for steering looseness or wander that may be caused by loose wheel bearings.

   Type of abnormal noise
   a. ____________________
   b. ____________________
   c. ____________________

   Possible causes
   a. ____________________
   b. ____________________
   c. ____________________

   Steering wander and looseness

   ☐ Yes ☐ No

2. Use a dial indicator to measure the endplay on the front wheel bearing hubs with the wheel installed on the hub.

   Endplay left side __________________ Endplay right side______________________

   Specified endplay __________________

   Necessary repairs ____

3. Loosen and remove the cotter pin, lock nut, and drive axle nut before raising the vehicle. ☐

4. Raise the vehicle on a lift and remove the front wheels. ☐

Task Completed

☐ 5. Remove the brake calipers and brake rotors. Use a length of wire to tie the calipers to the chassis.

6. Use a dial indicator to measure the endplay directly on the front wheel bearing hubs.

Endplay left side ____________________ Endplay right side_________________________

Specified endplay ___________________

Necessary repairs ____

☐ 7. If a wheel speed sensor for the antilock brake system (ABS) is integral in the front wheel hubs, disconnect the wheel speed sensor connectors.

☐ 8. Remove the hub-to-knuckle bolts, and place the transaxle in park.

☐ 9. Use the proper puller to remove the wheel bearing hub from the drive axle.

☐ 10. Install the new hub and bearing assembly on the drive axle splines, and install a new drive axle nut. Tighten the drive axle nut to pull the hub onto the splines. Do not tighten this nut to the specified torque at this time.

11. Place the transaxle in neutral and install the wheel bearing hub bolts. Tighten these bolts to the specified torque.

Specified wheel bearing hub bolt torque ____

Actual wheel bearing hub bolt torque ____

12. Install the wheel sensor connectors, rotors, and calipers. Tighten the caliper mounting bolts to the specified torque. Place a large punch between the rotor fins and the caliper, and tighten the drive axle nut to the specified torque.

Specified caliper bolt torque ____

Actual caliper bolt torque ____

Specified drive axle nut torque ____

Actual drive axle nut torque ____

13. Install the wheels in their original positions, and tighten the wheel nuts to the specified torque.

Specified wheel nut torque ____

Actual wheel nut torque ____

14. Lower the vehicle onto the shop floor, and tighten the drive axle nut to the specified torque. Install the lock nut and a new cotter pin.

Specified drive axle nut torque ____

Actual drive axle nut torque ____

Are the lock nut and cotter pin properly installed and tightened?

Instructor check ____

15. Road test the car and listen for abnormal wheel bearing noises.

Wheel bearing noise: ☐ Satisfactory ☐ Unsatisfactory

Instructor's Response ____

____

____

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Name ______________________________ **Date** ____________________

Diagnose Wheel Bearings

Upon completion of this job sheet, you should be able to diagnose wheel bearings.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task D-2: Remove, inspect, and service or replace front and rear wheel bearings.

Tools and Materials

A vehicle with wheel bearing noise or bearing noise from another source

Describe the Vehicle Being Worked On:

Year ________ Make ________________ Model ______________________

VIN ________________________ Engine type and size ____________________

Procedure

Task Completed

1. Road test the vehicle, listen for any abnormal wheel noises, and check for steering looseness and wander that may be caused by loose wheel bearings. ☐
2. Wheel bearing noise: ☐ Satisfactory ☐ Unsatisfactory
3. Is the bearing noise coming from the front or rear of the vehicle? ☐ Front ☐ Rear
4. Is this noise more noticeable when turning a corner at low speeds? ☐ Yes ☐ No
5. Is this noise more noticeable during acceleration? ☐ Yes ☐ No
6. Is this noise more noticeable during deceleration? ☐ Yes ☐ No
7. Is this noise more noticeable when driving at a steady speed? ☐ Yes ☐ No

   If the answer to this question is yes, state the speed when the bearing noise is most noticeable. ____
8. Is this noise most noticeable when driving down a narrow street at a steady low speed?
   ☐ Yes ☐ No
9. State the exact cause of the bearing noise, and explain the reason for your diagnosis.
   ____
   ____
   ____

Instructor's Response ____
____
____

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Name ______________________________ Date ____________________

Clean, Lubricate, Install, and Adjust Nonsealed Wheel Bearings

Upon completion of this job sheet, you should be able to clean, lubricate, install, and adjust nonsealed wheel bearings.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task D-2: Remove, inspect, and service or replace front and rear wheel bearings.

Tools and Materials

A vehicle with tapered roller-type front wheel bearings or a front-wheel-drive car with tapered roller-type rear wheel bearings

A floor jack and safety stands, or a lift for raising the vehicle

Wheel bearing grease

Cleaning solution

Seal drivers

Torque wrench

Describe the Vehicle Being Worked On:

Year ________ Make ________________ Model ______________________

VIN ________________________ Engine type and size ____________________

Procedure

Task Completed

1. Raise the vehicle on a lift with the chassis supported on the lift. ☐
2. Chalk mark the wheels in relation to the studs; remove the wheels, wheel hubs, and brake drums or rotors. ☐
3. Remove the inner hub seal and wheel bearings from the hub. ☐
4. Clean the hub and bearings with an approved cleaning solvent.

   Are the hub and bearings properly cleaned? ☐ Yes ☐ No

   Instructor check ____
5. Inspect the wheel bearings, bearing cones, and hubs.

Type of defects	Necessary replacement parts
a. ________________	a. ________________
b. ________________	b. ________________
c. ________________	c. ________________

6. Inspect all bearing-related conditions such as lubrication, alignment, spindle condition, and hub condition. State the cause(s) of the bearing defects listed in step 5.
   a. ____________________
   b. ____________________
   c. ____________________

7. Repack the wheel bearings and hub with the car manufacturer's specified wheel bearing grease.

   Are the wheel bearings and hub repacked with the manufacturer's recommended grease? ☐ Yes ☐ No

   Instructor check ____________________

8. Install a new inner hub seal with the proper seal driver. Lubricate the seal lips with a light coating of the car manufacturer's recommended wheel bearing grease.

   Is the new inner hub seal properly installed? ☐ Yes ☐ No

   Instructor check ____________________

9. Inspect, clean, and lubricate the spindles and seal contact area.

   Spindle and seal contact condition: ☐ Satisfactory ☐ Unsatisfactory

   If unsatisfactory, state necessary repairs. ____________________

   ____

   Is the spindle and seal contact area properly cleaned and lubricated? ☐ Yes ☐ No

   Instructor check ____________________

10. Install the wheel hubs, wheel bearings, washer, and retaining nut. Adjust the wheel bearing retaining nut to the specified initial torque.

    Specified initial wheel bearing torque ____________________

    Actual initial wheel bearing torque ____________________

11. Back off the wheel bearing retaining nut the specified amount.

    Specified portion of a turn to back off the wheel bearing retaining nut ____________

    Actual portion of a turn the wheel bearing retaining nut is backed off ____________

12. Tighten the wheel bearing retaining nut to the final specified torque.

    Specified final wheel bearing retaining nut torque ____________________

    Actual final wheel bearing retaining nut torque ____________________

13. Install a new cotter pin through the wheel bearing retaining nut and spindle opening.

    Is the new cotter pin properly installed? ☐ Yes ☐ No

    Instructor check ____________________

14. Install the wheel bearing dust covers. Install the wheels in their original position, and tighten the wheel nuts to the specified torque.

    Specified wheel nut torque ____

    Actual wheel nut torque ____

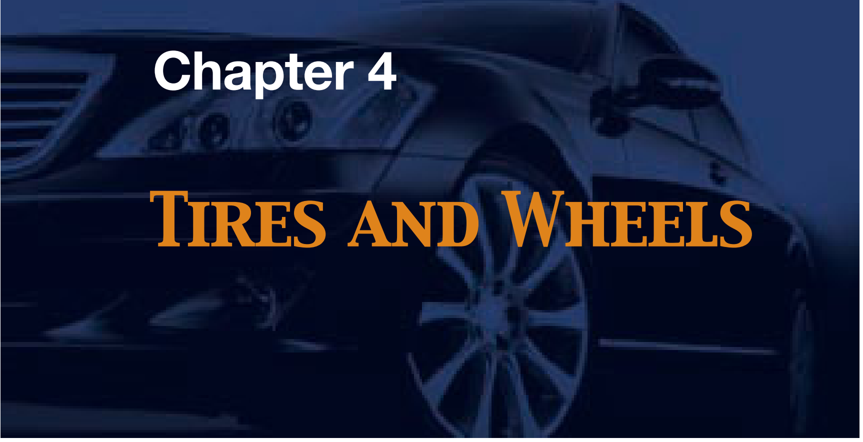
15. Road test the car and listen for abnormal wheel bearing noises.

    Wheel bearing noise: ☐ Satisfactory ☐ Unsatisfactory

Instructor's Response ____

____

____



Chapter 4

Tires and Wheels

Upon completion and review of this chapter, you should be able to understand and describe:

- General tire function.
- Typical tire construction, and identify the purpose of each component in a tire.
- Three types of tire ply and belt designs.
- Tire ratings, and explain the meaning of each designation in the rating.
- The purpose of the tire performance criteria (TPC) rating.
- The difference between all-season tires and conventional tires.
- Two different types of tire load ratings.
- The tire tread wear rating.
- The Uniform Tire Quality Grading (UTQG) designations.
- The precautions to be observed when selecting replacement tires.
- Tire contact area, free tire diameter, and rolling tire diameter.
- The tire motion forces while a tire-and-wheel assembly is rotating on a vehicle.
- The importance of tire design quality as it relates to the tire motion forces.
- Wheel offset.
- Wheel tramp, and explain how static unbalance causes wheel tramp.
- Wheel shimmy, and describe how dynamic unbalance results in wheel shimmy.
- Various types of tire pressure monitoring systems.
- The advantage of nitrogen tire inflation.
- Various types of vibrations.

Introduction

Although tires are often taken for granted, they contribute greatly to the ride and steering quality of a vehicle. Tires also play a significant role in vehicle safety. Improper types of tires, incorrect inflation pressure, and worn-out tires create a safety hazard. When tires and wheels are out of balance, tire wear and driver fatigue are increased, which can create a driving hazard. Tires serve the following functions:

1. Tires cushion the vehicle ride to provide a comfortable ride for the occupant.
2. Tires must firmly support the vehicle weight.
3. Tires must develop traction to drive and steer the vehicle under a wide variety of road conditions.
4. Tires contribute to directional stability of the vehicle and must absorb all the stresses of accelerating, braking, and centrifugal force in turns.

Tire Design

Tire construction varies depending on the manufacturer and the type of tire. A typical modern tire contains these components (Figure 4-1):

1. **Bead wire**
2. Bead filler
3. **Liner**
4. Steel reinforcement in the sidewall
5. Sidewall with hard side compound
6. Rayon carcass plies
7. Steel belts
8. Jointless belt cover
9. Hard undertread compound
10. Hard high-grip tread compound

The **bead wire** is a group of wire strands that retain the bead on the wheel rim.

The tire **liner** is made from synthetic gum rubber and seals the inside of the tire.

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Chapter 4, page 120

The bead wire contains several turns of bronze-coated steel wire in a continuous loop. This bead wire is molded into the tire at the inner circumference and wrapped in the cord plies. The bead wire anchors the tire to the wheel. The **bead filler** above the bead reinforces the sidewall and acts as a rim extender.

Tire **sidewalls** are made from a blend of rubbers which absorbs shocks and impacts from road irregularities, prevents damage to the plies, and also contains antioxidants and other chemicals that are gradually released to the surface of the sidewall during the life of the tire. These antioxidants help keep the sidewall from cracking and protect it from ultraviolet radiation and ozone attack. Since the sidewall must be flexible to provide ride quality, minimum thickness of this component is essential. Tire manufacturers have reduced sidewall thickness by 40 percent in recent years to reduce weight and heat buildup, improve ride quality, reduce rolling resistance, and improve fuel economy. A lettering and numbering arrangement for tire identification is located on the outside of the sidewall.

The **cord plies** surround both beads and extend around the inner surface of the tire to enable the tire to carry its load. The plies are molded into the sidewalls. Each ply is a layer of rubber with parallel cords imbedded in its body. The load capacity of a tire may be increased by adding more cords in each ply or by installing additional plies. The most common materials in tire plies are polyester, rayon, and nylon. Passenger car tires usually have two-cord plies, whereas many trucks and recreation vehicles are equipped with six- or eight-ply tires to carry the heavier loads of these vehicles. In general, tires with more plies have stiffer sidewalls, which provide less cushioning and reduced ride quality.

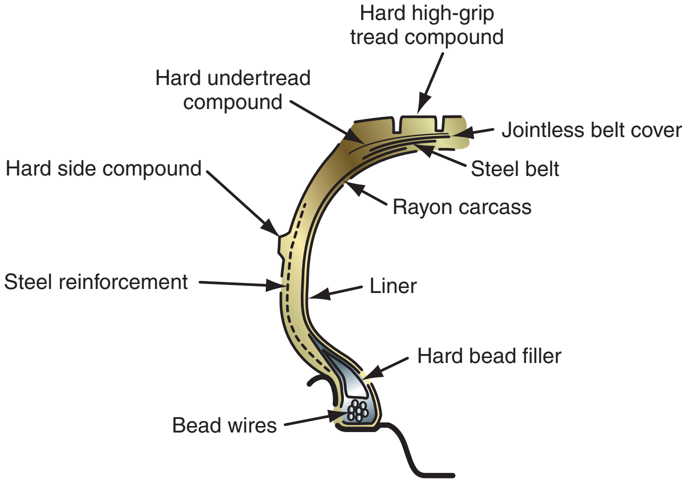

FIGURE 4-1 **Tire design.**

Tire belts are positioned between the tread and the cord plies.

Tire treads are mounted between the sidewalls.

Synthetic rubber compounds are developed in laboratories, whereas natural rubber is found in nature.

Steel is the most common material in **tire belts**, although other belt materials such as polyester have been used to some extent. Many tires contain two steel belts. The tire belts restrict ply movement and provide tread stability and resistance to deformation. This belt action provides longer tread wear and reduces heat buildup in the tire. Steel belts expand as wheel speed and tire temperature increase. Centrifugal force and belt expansion tend to tear the tire apart at high speeds and temperatures. Therefore, high-speed tires usually have a nylon jointless **belt cover**. This nylon belt cover contracts as it is heated and helps hold the tire together, providing longer tire life, improved stability, and better handling.

Tire treads are made from a blend of rubber compounds that are very resistant to abrasion wear. Spaces between the tire treads allow tire distortion on the road without scrubbing, which accelerates wear. Modern automotive tires contain two layers of tread materials. The first tread layer is designed to provide cool operation, low rolling resistance, and durability. The outer layer, or tread, is designed for long life and maximum traction. Tread rubber is a blend of many different synthetic and natural rubbers. Tire manufacturers may use up to thirty different types of **synthetic rubber** and eight types of natural rubber in their tires. Manufacturers blend these synthetic and natural rubbers in both tread layers to provide the desired traction and durability. Tire treads must provide traction between the tire and the road surface when the vehicle is accelerating, braking, and cornering. This traction must be maintained as much as possible on a wide variety of road surfaces. For example, on wet pavement, tire treads must be designed to drain off water between the tire and the road surface. This draining action is extremely important to maintaining adequate acceleration, braking, and directional control. Lines cut across the tread provide a wiping action, which helps dry the tire-road contact area. Most tire manufacturers add a permablack compound to the rubber in their tires to maintain new-tire appearance throughout the life of the tire.

The synthetic gum rubber liner is bonded to the inner surface of the tire to seal the tire. Nearly all passenger car and light truck tires are the tubeless type. In these tires, the tire bead must provide an airtight seal on the rim, and both the tire and the wheel rim must be completely sealed. Some heavy-duty truck tires have inner tubes mounted inside the tire. On tube-type tires, the air is sealed in the inner tube, and the sealing qualities of the tire and wheel rim are not important. Designing tires is a very complex engineering operation. The average all-season tire contains the components (by weight) listed in Table 4-1.

Tire design varies depending on the operating conditions and the load capacity of the tire. A tire designed for improved steering and handling characteristics has a nylon bead reinforcement and a hard bead filler with a slim tapered profile (Figure 4-2). This type of tire is suitable for sports car operation because the design stiffens the tire and reduces tire deflection during high-speed cornering. However, this type of tire may provide slightly firmer ride quality.

TABLE 4-1 **TIRE COMPONENTS BY WEIGHT**

A typical P195/75-14 all-season tire contains:

Synthetic rubber (30 types)	2.49 kg
Carbon Black (8 types)	2.27 kg
Natural Rubber (8 types)	2.04 kg
Chemicals, waxes, oils, pigments, etc. (40 types)	1.36 kg
Steel cord for belts	0.68 kg
Polyester and nylon	0.45 kg
Bead wire	0.23 kg
Total weight	9.42 kg

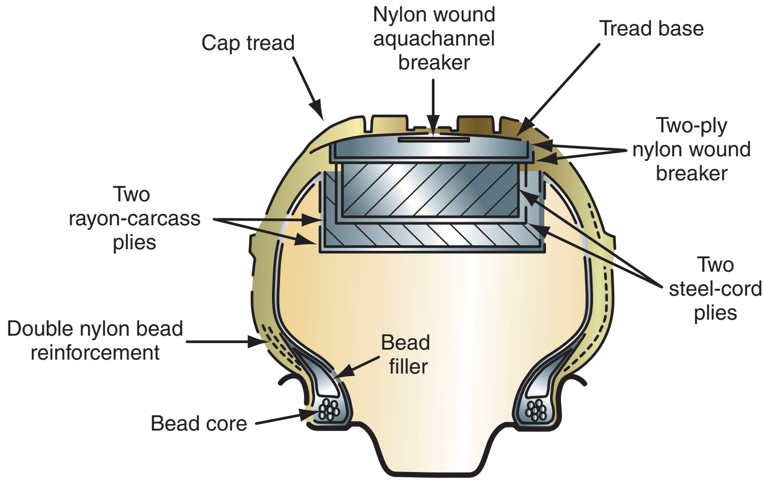

FIGURE 4-2 **Tires designed for improved steering and handling with a nylon bead reinforcement and a hard bead filler with a slim tapered profile.**

Tire Ply and Belt Design

The most commonly used tire designs are bias, belted bias, and belted radial. In **bias-ply** or **belted bias-ply tires**, the cords crisscross each other. These cords are usually at an angle of 25° to 45° to the tire centerline. The belt-ply cord angle is usually 5° less than the cord angle in the tire casing. Two plies and two belts are most commonly used, but four plies and four belts may be used in some tires. Compared to a bias-ply tire, a belted bias-ply tire has greater tread rigidity. The belts reduce tread motion during road contact. This action provides extended tread life compared to a bias-ply tire.

In **radial-ply tires**, the ply cords are arranged radially at a right angle to the tire centerline (Figure 4-3). Steel belts are most commonly used in radial tires, but other belt materials such as fiberglass, nylon, and rayon have also been used. The steel or fiberglass cords in the belts are crisscrossed at an angle of 10° to 30° in relation to the tire centerline. Many radial tires have two plies and two belts. Radial tires provide less rolling resistance, better steering characteristics, and longer tread life than bias-ply tires.

Regardless of the type of tire construction, the tire must be uniform in diameter and width. Radial runout refers to variations in tire diameter. A tire with excessive radial runout causes a tire thumping problem as the car is driven. When a tire has excessive variations in

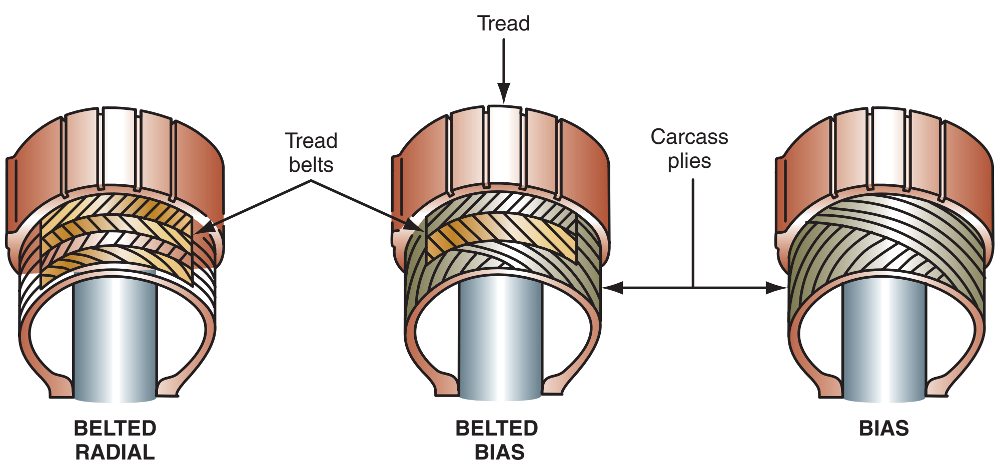

FIGURE 4-3 **Three types of tire construction: bias-ply, belted bias-ply, and belted radial-ply.**

A BIT OF HISTORY

In 1834 Charles Goodyear was a hardware merchant from Philadelphia with a great interest in a new substance imported from Brazil called rubber. When rubber was first imported to the United States, many entrepreneurs were interested in manufacturing products from rubber. However, these entrepreneurs soon discovered that rubber became bone-hard in cold weather, and then turned to a glue-like substance in very hot weather, and these characteristics ended the rubber manufacturing business at that time.

Charles Goodyear persisted in experimenting with rubber! He experimented with mixing magnesia powder, nitric acid, and sulfur with rubber to reduce its stickiness. These substances improved the rubber quality, but it still was not perfected. Goodyear was often financially bankrupt and he had difficulty obtaining enough money to feed his children. He was even jailed on some occasions for failure to pay his bills, and ill health often plagued him.

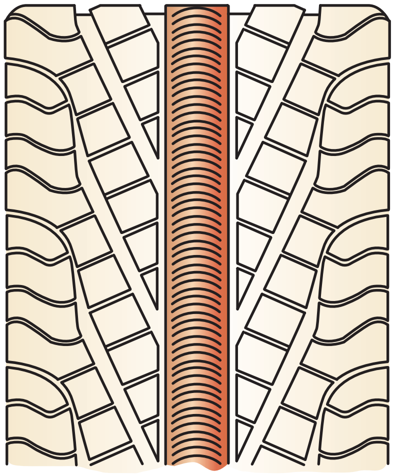

FIGURE 4-4 **Interlocking tread pattern for improved traction on icy roads.**

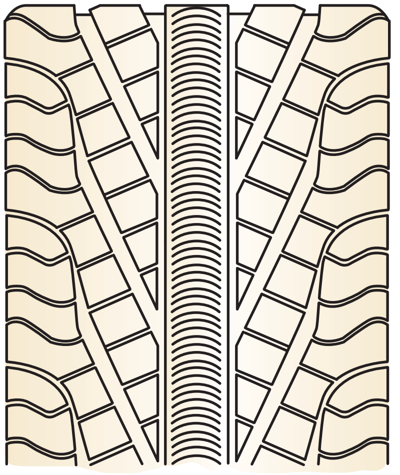

FIGURE 4-5 **Aquachutes propel water off the tire tread.**

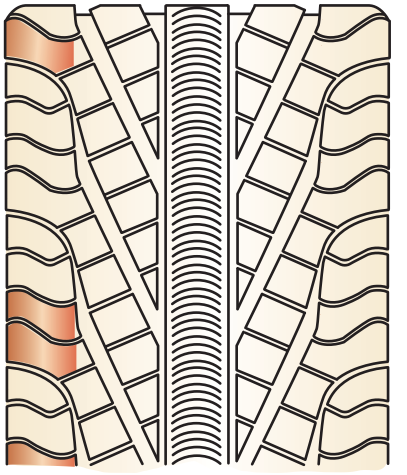

FIGURE 4-6 **Reinforced tread shoulders improve tread gripping quality while cornering.**

A BIT OF HISTORY

(continued)

By accident Goodyear discovered that extreme heat changed the rubber to a weatherproof, gum-like material. He found that pressurized steam applied to rubber for 4 to 6 hours at 270°F (132°C) provided the most uniform rubber. Goodyear was now able to obtain financial backing to produce rubber. Goodyear was plagued with patent right problems and those trying to steal his rubber patents. However, he did succeed in discovering modern rubber! Neither Charles Goodyear nor his family was ever connected with the company named in his honor, today's Goodyear Tire and Rubber Company.

width, this condition is called lateral runout. A tire with excessive lateral runout causes the chassis to "waddle" when the car is driven.

The tire plies and belts must be level across the tread area. If the plies and/or belts are not level across the tread area, the tire is cone shaped. This condition is referred to as tire conicity. When a front tire has conicity, the steering may pull to one side as the car is driven straight ahead. A rear tire with conicity will not affect the steering as much as a front tire with conicity.

Tire Tread Design

Vehicle tires have many different tire treads designed to provide the tire performance desired by the tire and vehicle manufacturers. A typical modern tire tread has these features:

1. An interlocking tread pattern for improved tread gripping quality on icy or slick roads (Figure 4-4).
2. Deeply carved aquachutes to propel water off the tread and away from the tire to reduce the possibility of **hydroplaning** when driving on wet pavement (Figure 4-5).
3. Reinforced tread shoulders to improve tread gripping quality when turning corners on dry pavement (Figure 4-6).

One tire manufacturer installs 2 to 3 billion microscopic hollow shells or bubbles in the tread material on one brand of their tires. These hollow shells are installed to 60 percent of the tread depth, and add rigidity to the tread material. When these hollow shells contact the road surface they break open, and the shell edges provide a gripping effect to improve traction. When driving on wet pavement, each time a hollow shell contacts the road surface and breaks open, a small amount of water is pulled into the hollow shell (Figure 4-7). Because this action is occurring at the millions of hollow shells in contact with the road surface, water is removed from between the tread and the road surface. This action reduces the possibility of hydroplaning. As the tire continues to rotate, water is expelled from the hollow shells when they move out of contact with the road surface.

Tire Manufacturing Defects

Manufacturing defects may be covered by the tire manufacturer's warranty. Possible defects include the following:

1. Separations and bulges, including tread or sidewall separation, or an open tread splice
2. Tread chunking, tearing, groove cracking, and shoulder cracking

HOW SHELLED MICRO-BUBBLES WORK

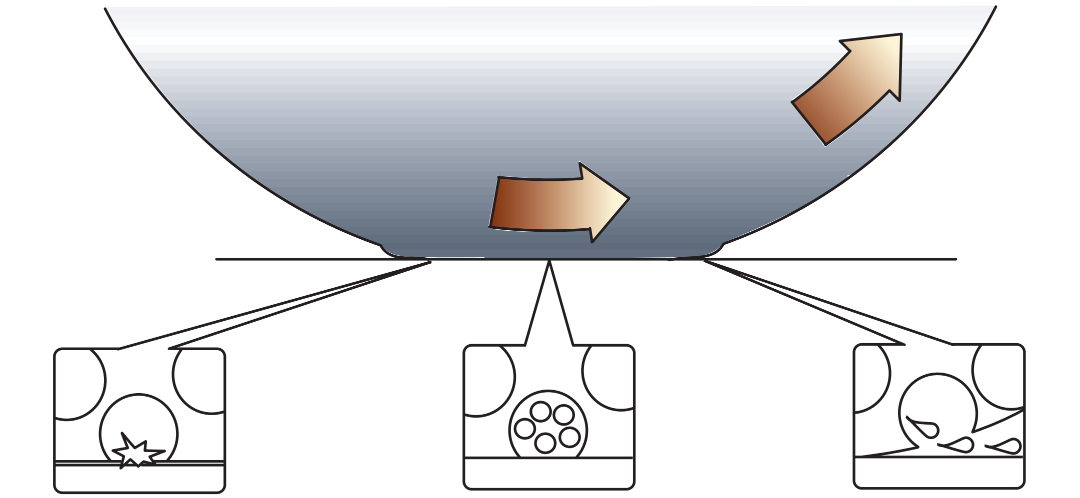

FIGURE 4-7 **Advantages of micro-bubbles in the tire tread.**

3. Sidewall circumference fatigue, cracking, and weather cracking
4. Bead chafing, broken wires, or a pulled bead
5. Breaks in the sidewall or tread areas
6. Excessive radial or lateral runout
7. **Conicity**

Tire Ratings and Sidewall Information

A lot of essential information is molded into the sidewall of the average passenger car and light truck tire, including the tire rating. The tire rating is a group of letters and numbers that identify the tire type, section width, aspect ratio, construction type, rim diameter, load capacity, and speed symbol. The tire in Figure 4-8 has a P215/65R15 95H rating.

P indicates a passenger car tire. The number 215 is the size of the tire in millimeters measured from sidewall to sidewall with the tire mounted on the recommended rim width.

Aspect Ratio and Ply Design

The number 65 indicates the aspect ratio, which is the ratio of the height to the width (Figure 4-9). With a 65 aspect ratio, the tire's height is 65 percent of its width. The letter R indicates radial-ply tire construction. If the tire construction was indicated by the letters A B, the tire has a belted, bias-ply construction. The letter D represents diagonal bias-ply tire design.

Rim Diameter and Load Rating

The number 15 is the rim diameter in inches. The load index is represented by the number 95. The tire in Figure 4-8 has load rating of 1,521 pounds. Various numbers represent different maximum loads. The maximum load is shown on the tire in pounds (lb) and kilograms (kg) together with the maximum inflation pressure in pounds per square inch (psi) and kilograms (kg). Some tire manufacturers have used the letters B, C, or D to indicate the **load rating**. The letter B indicates the lowest load rating and the letter C represents a higher load rating. A tire with a D load rating is designed for light-duty trucks, and this tire will safely carry a load of 2,623 pounds when inflated to 65 psi.

A BIT OF HISTORY

(continued)

Today there is a cultivated rubber tree for every two human beings on earth, and three million people are employed collecting the rubber from the trees in various countries. The United States imports approximately half of the rubber in the world and synthesizes an equal amount from petroleum. About 300,000 people in the United States are employed in the rubber industry, and they produce approximately $6 billion worth of products each year.

Belted bias-ply tires have steel or polyester belts between the cord plies and the tread.

Radial runout may be defined as variations in tire diameter.

Lateral runout may be defined as variations in tire width.

Tire conicity refers to a condition where the plies and/or belts are not level across the tire tread. When a tire has conicity, the plies and/or belts are somewhat cone shaped.

Hydroplaning occurs when water on the pavement is allowed to remain between the pavement and the tire tread contact area. This action reduces friction between the tire tread and the road surface, and can contribute to a loss of steering control.

Aspect ratio is the percentage of a tire's height in relation to its width.

The aspect ratio may be referred to as the tire profile or series number.

The **load rating** indicates the tire's load-carrying capability.

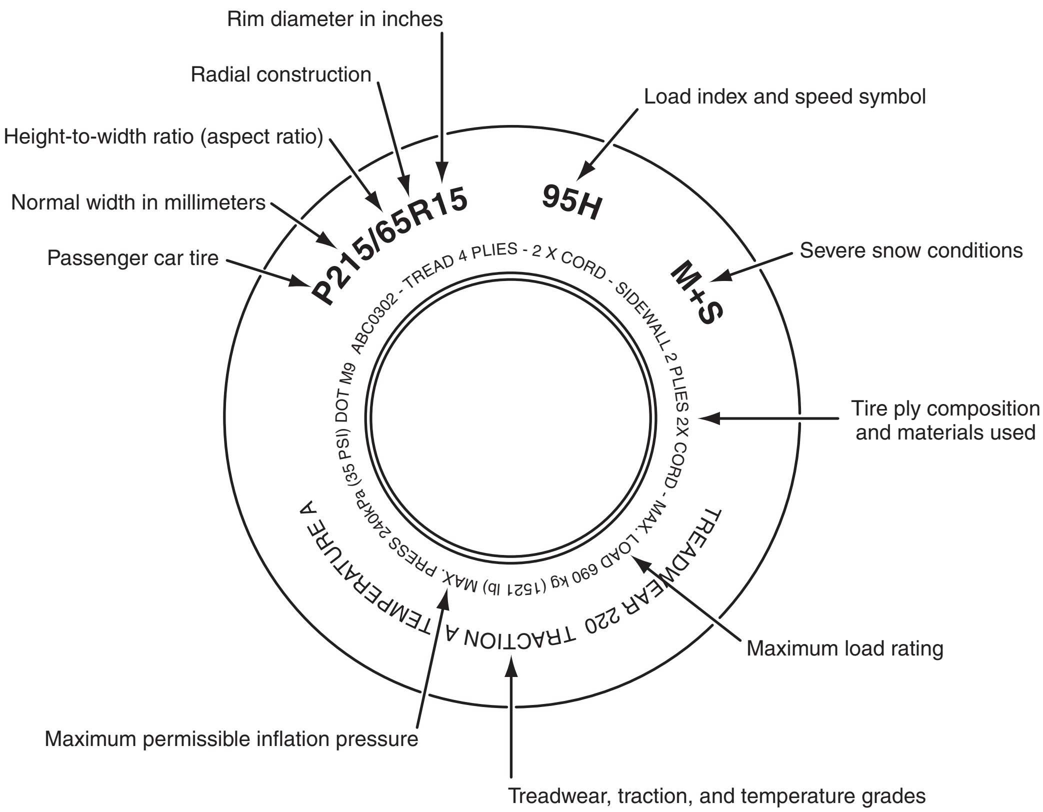

FIGURE 4-8 **Tire sidewall information.**

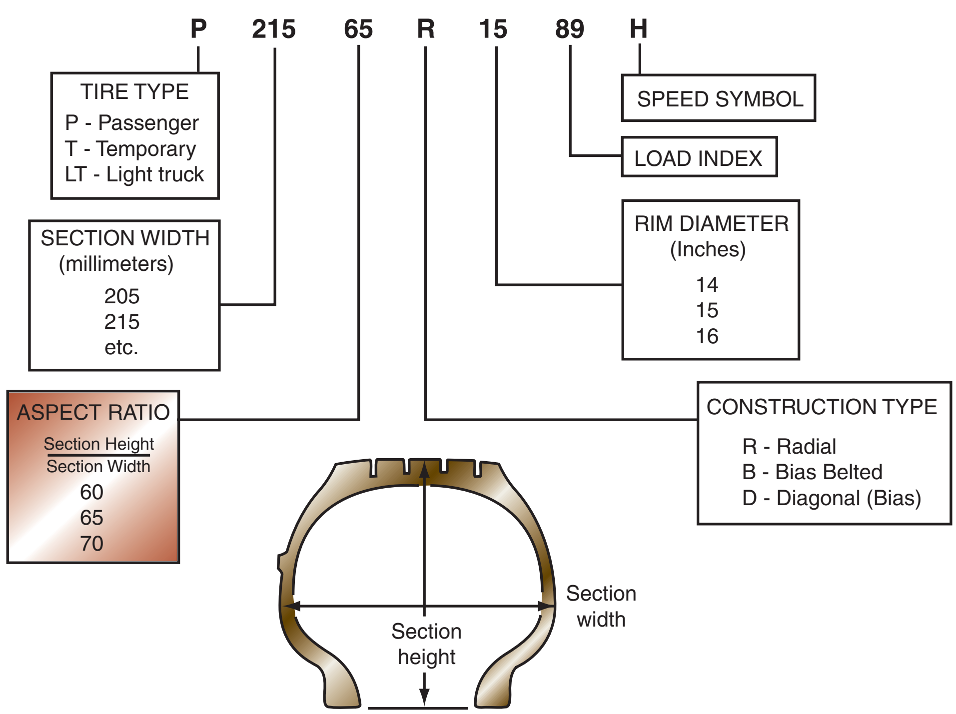

FIGURE 4-9 **Tire aspect ratio is the percentage of the tire's height in relation to its width.**

Speed Rating

The letter H indicates the tire has a 130 miles per hour (mph) **speed rating**. Other speed ratings are:

Q – 99 mph
S – 112 mph
T – 118 mph
U – 124 mph
V – above 130 mph without service description
V – 149 mph with service description
Z – above 149 mph
W – 168 mph
Y – 186 mph

The **speed rating** indicates the tire's capability to withstand high speed.

Tire speed ratings do not suggest that vehicles can always be driven safely up to the maximum designated speed rating, because many different road and weather conditions may be encountered. Tire manufacturers do not endorse the operation of a vehicle in an unlawful or unsafe manner. Speed ratings are based on laboratory tests, and these ratings are not valid if tires are worn out, damaged, altered, underinflated, or overloaded. The condition of the vehicle may also affect high-speed operation.

Department of Transportation (DOT) Tire Grading

The United States Department of Transportation (DOT) regulations demand that all tire manufacturers grade all passenger car tires, except mud and snow tires, according to tread wear, traction, and temperature. This DOT tire grading may be referred to as the **Uniform Tire Quality Grading (UTQG) System**.

Tread Wear Rating

Tread wear ratings allow customers to compare tire tread life expectancies. The tread wear rating is based on the tire tread wear when tested under specific conditions on a government test track. A baseline tire has a tread wear rating of 100. A tire with a 150 tread wear rating would last 1.5 times as many miles on the test track as the baseline tire with a 100 tread wear rating. Tread wear ratings are valid only for comparison within a manufacturer's product line, and these ratings are not valid for comparisons between tire manufacturers.

Traction Rating

Traction ratings indicate the braking capabilities of a tire. To determine the traction rating, ten skid tests are completed on wet asphalt and concrete surfaces. Test conditions are carefully controlled to maintain test uniformity. The results of the ten skid tests are averaged, and the traction rating is designated as A, B, or C. An A traction rating indicates the best traction, a B rating indicates intermediate traction, and a C rating indicates acceptable traction.

Temperature Rating

The **temperature rating** indicates the tire's ability to withstand extreme heat during tire operation. To obtain the temperature rating, tires are tested on a laboratory test wheel. The temperature rating indicates how long the tire will last on the test wheel. Extremely high temperatures may cause tire materials to degenerate and thus reduce tire life or cause tire failure. The temperature ratings are A for best, B for intermediate, and C for acceptable.

DOT regulations also require tire manufacturers to place the following information on tire sidewalls:

1. Size
2. Load range

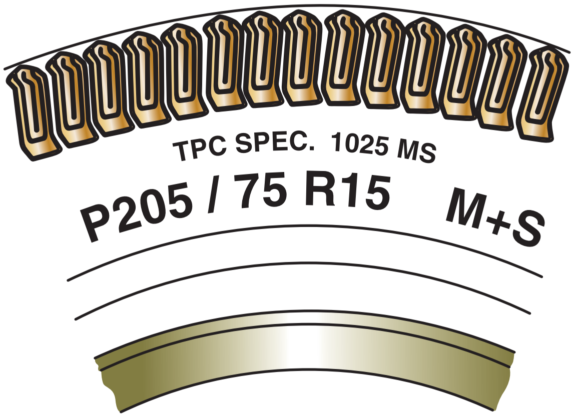

FIGURE 4-10 Tire performance criteria (TPC) number.

3. Maximum load
4. Maximum pressure
5. Number of plies under the tread and in the sidewalls
6. Manufacturer's name
7. Tubeless or tube-type construction
8. Type of carcass construction
9. DOT approval number, including the manufacturer's code number and date of manufacture

Some tires have a **tire performance criteria (TPC)** number molded on the sidewall (Figure 4-10). This number represents that the tire meets the car manufacturer's performance standards for traction, endurance, dimensions, noise, handling, and rolling resistance. Most car manufacturers assign a different TPC number to each tire size. Replacement tires should have the same ratings and TPC number as the original tires.

Specialty Tires

Sport Utility Vehicle (SUV) and 4 × 4 Tires

SUV tires may be classified for use on pavement or off-road. SUV tires have greater load-carrying capacity compared to passenger car tires, because of the extra loads that may be carried in an SUV. A typical pavement SUV tire has these features:

1. A silica tread compound that provides low noise levels and exceptional wet braking capability.
2. An enhanced casing system and a stable tire contact area that supplies even tread wear and responsive handling quality.
3. Larger cables in the steel belts to provide increased strength and durability.
4. Full-depth, interlocking sections in the tread that supply excellent wet and snow traction.

Compared to SUV tires for use on pavement, off-road SUV tires have stronger tread rubber to prevent cutting and chipping. Off-road SUV tires may also have thicker belt wire and more belt strands.

Tires designed for 4 × 4 vehicles may have some of the same features as SUV tires. A typical 4 × 4 tire has these additional features:

1. Two wide circumference grooves with a stepped profile to reduce hydroplaning.
2. Staggered shoulder blocks in the tread to improve lateral grip on slopes.

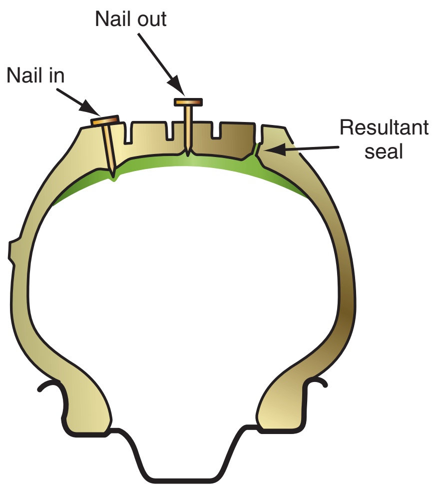

FIGURE 4-11 **Puncture sealing tire.**

3. Gradual profile changes in the shoulder area of the tread to provide progressive breakaway during hard cornering.
4. Additional rubber at the base of the tread to reduce the possibility of tire damage.

Puncture sealing tires are available as an option on certain car lines, and some rubber companies sell these tires in the replacement tire market. These tires contain a special rubber sealing compound applied under the tread area during the manufacturing process. When a nail or other object up to 3/16 inch in diameter punctures the tread area, it picks up a coating of sealant. If the object is removed, the sealant sticks to the object and is pulled into the puncture. This sealant completely fills the puncture and forms a permanent seal to maintain tire inflation pressure (Figure 4-11). Puncture sealing tires usually have a special warranty. These tires can be serviced with conventional tire changing and balancing equipment. When repairing tires, the maximum repairable puncture size is ¼ inch.

Mud and snow tires are available in various ply and belt designs. These tires provide increased traction in snow or mud compared to conventional tires. Mud and snow tires are identified with an MS suffix after the tire performance criteria (TPC) number on the tire sidewall. When snow tires are installed on a vehicle, these tires should be the same size and type as the other tires on the vehicle. In areas where snow is encountered, all-season tires have replaced snow tires to a large extent. Studded tires provide improved traction on ice, but these tires are prohibited by law in many states because their use resulted in road surface damage.

Many tires sold today are classified as **all-season tires**. These tires have a 37 percent higher average snow traction compared to non-all-season tires. All-season tires may have slightly improved performance in areas such as wet traction, rolling resistance, tread life, and air retention. Improvements in tread design and tread compounds provide the superior quality in all-season tires. All-season tires are usually identified by the letters MS (for mud and snow) on the sidewall.

Replacement Tires

Most tires have tread wear indicators built into the tread. When the tread wears a specific amount, the wear indicators appear as bands across the tread (Figure 4-12). Some car manufacturers recommend tire replacement when the wear indicators appear in two or more tread grooves at three locations around the tire.

If **replacement tires** have a different size or construction type than the original tires, vehicle handling, ride quality, speedometer/odometer calibration, and antilock brake system (ABS) operation may be seriously affected. When replacement tires are a different

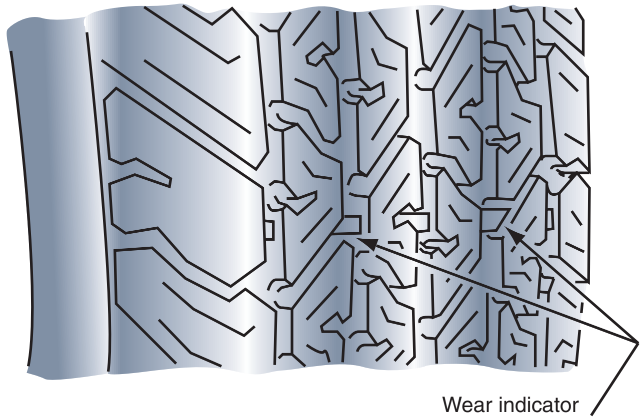

FIGURE 4-12 **Tread wear indicators.**

size than the original tires, the vehicle ground clearance and tire-to-body clearance may be altered. Steering and braking quality may be seriously affected if different sizes or types of tires are installed on a vehicle. This does not include the compact spare tire, which is intended for temporary use. Many vehicles manufactured in recent years are equipped with antilock brakes (ABS). When different-sized tires are installed on these vehicles, the ABS operation is abnormal, which may result in serious braking defects. When selecting replacement tires, the following precautions must be observed to maintain vehicle safety:

1. Replacement tires must be installed in pairs on the same axle. Never mix tire sizes or designs on the same axle. If it is necessary to replace only one tire, it should be paired with the tire having the most tread to equalize braking traction.
2. The tire load rating must be adequate for the vehicle on which the tire is installed. Light-duty trucks, station wagons, and trailer-towing vehicles are examples of vehicles that require tires with higher load ratings than passenger car tires.
3. Snow tires should be the same type and size as the other tires on the vehicle.
4. A four-wheel-drive and all-wheel drive vehicle should have the same type and size of tires on all four wheels.
5. Do not install tires with a load rating less than the car manufacturer's recommended rating.
6. Replacement tire ratings should be equivalent to the original tire ratings in all rating designations.
7. When combining different tires front to rear on a vehicle, consult Table 4-2, and check the car manufacturer's or tire manufacturer's recommendations.

Tire Valves

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The **tire valve** allows air to flow into the tire, and it is also used to release air from the tire. The core in the center of the valve is spring loaded and allows air to flow inward while the tire is inflated (Figure 4-13). Once the tire is inflated, the valve core seats and prevents air flow out of the tire. The small pin on the outer end of the valve core may be pushed to unseat the valve core and release air from the tire. An airtight cap on the outer end of the valve keeps dirt out of the valve, and provides an extra seal against air leakage. A deep groove is cut around the inner end of the tire valve. When the valve assembly is pulled into the wheel opening, this groove seals the valve in the opening. Steel valve stems are installed in some wheels. The lower end of the valve stem is threaded, and a nut retains the valve stem in the wheel (refer to Figure 4-13). Steel washers and sealing washers are located on the valve stem on the inside and outside of the wheel. The sealing washers are positioned next to the wheel.

TABLE 4-2 ***FRONT TO REAR TIRE COMBINATIONS***

Construction		Bias on Front (Read down for rear)			Belted Bias on Front (Read down for rear)				Radial on Front (Read down for rear)		
	Series (Profile)	78 Series	70 Series	60/50 Series	78 Series	70 Series	60/50 Series	Metric	78 Series	70 Series	60/50 Series
Bias on Rear (Read across for front)	Conventional (83 Series)	A	No	No	A	No	No	No	No	No	No
	78 Series	p	A	No	A	No	No	No	No	No	No
	70 Series	A	P	No	A	A	No	No	No	No	No
	60/50 Series	A	A	P	A	A	A	No	No	No	No
Belted Bias on Rear (Read across for front)	78 Series	A	A	No	P	A	No	No	No	No	No
	70 Series	A	A	No	A	P	No	No	No	No	No
	60/50 Series	A	A	A	A	A	P	No	No	No	No
Radial on Rear (Read across for front)	Metric	A	A	No	A	A	No	P	A	A	No
	78 Series	A	A	No	A	A	No	A	P	A	No
	70 Series	A	A	No	A	A	No	A	A	P	No
	60/50 Series	A	A	A	A	A	A	A	A	A	P

P: Preferred applications. For best all-around car handling performance, tires of the same size and construction should be used on all wheel positions.
A: Acceptable but not preferred applications. Consult the car owner's manual and do not apply if vehicle manufacturer recommends against the application.
NO: Not recommended.

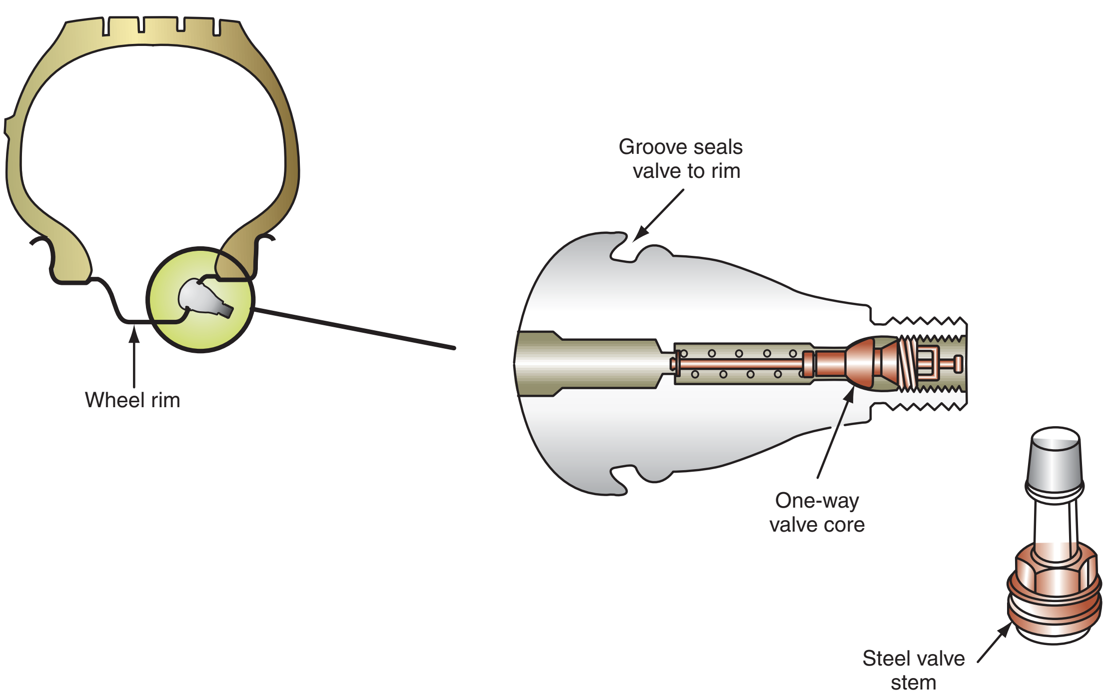

FIGURE 4-13 **Valve stems and cores.**

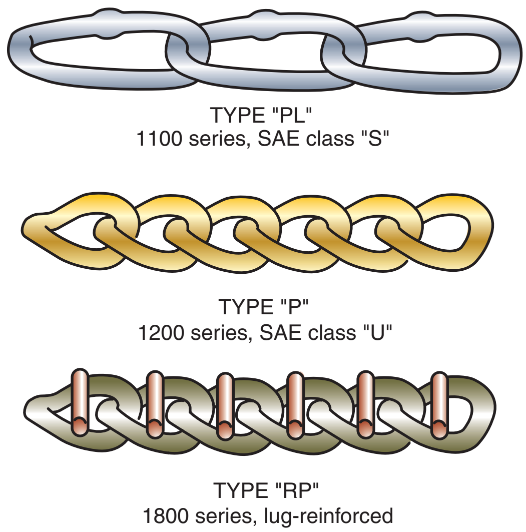

FIGURE 4-14 **Types of tire chains.**

Tire Chains

Tire chains are made from steel and wrap around the tire to improve traction.

Tire chains may be used in emergency situations such as driving on snow-covered or ice-covered mountain roads. Most tire manufacturers do not recommend the use of tire chains. Use only SAE class "S" tire chains unless specified by the vehicle and tire manufacturer. Chain types include class S, type P, and type RP (Figure 4-14). These chains must be the proper size and must be installed tightly with the ends secured. Always follow the chain manufacturer's recommended installation procedure. While using chains, driving speed should be reduced. If the chains are heard striking the vehicle body, stop immediately and tighten the chains to prevent body damage.

Compact Spare Tires

Compact spare tires save onboard storage space, but are designed for very limited operation.

Because cars have been downsized in recent years, space and weight have become major concerns for vehicle manufacturers. For this reason, many car manufacturers have marketed cars with **compact spare tires** to save weight and space. The high-pressure minispare tire is the most common type of compact spare (Figure 4-15). This compact spare rim is usually four inches wide, but is one inch larger in diameter than the other rims on the vehicle. The compact spare rim should not be used with standard tires, snow tires, wheel covers, or trim rings. Any of these uses may result in damage to these items or other parts of the vehicle. The compact spare should be used only on vehicles that offer it as original equipment. Inflation pressure

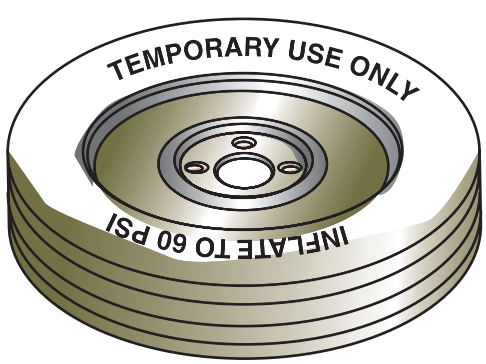

FIGURE 4-15 **Compact, high-pressure, minispare tire.**

in the compact spare should be maintained at 60 psi (415 kPa). The compact spare tire is designed for very temporary use until the conventional tire can be repaired or replaced. Limit driving speed to 50 mph (80 kph) when the high-pressure minispare is installed on a vehicle.

The space-saver spare tire must be inflated with a special compressor. Battery voltage is supplied to the compressor from the cigarette lighter. This type of compact spare should be inflated to 35 psi (240 kPa). After the tire is inflated, be sure there are no folds in the sidewalls.

The lightweight-skin spare tire is a bias-ply tire with a reduced tread depth to provide an estimated 2,000 miles (3,200 km) of tread life. This type of spare tire is also designed for emergency use only, and driving speed must be limited to 50 mph (80 km/h) when this tire is installed on a vehicle. Always inflate the lightweight-skin spare tire to the pressure specified on the tire placard.

Run-Flat Tires

Some tire manufacturers have recently designed **run-flat tires**. Run-flat tires may be called extended mobility tires (EMT). These tires are standard equipment on the 1995 and later model Corvette and the Plymouth Prowler. Run-flat tires eliminate the need for a spare tire and a jack, saving both weight and space. Run-flat tires are designed with stiffer sidewalls that will partially support the vehicle weight without air pressure in the tire.

Run-flat tires are designed to operate at zero air pressure for limited mileage. Run-flat tires may be called self-supporting, extended mobility, or zero-pressure tires.

Run-flat tires must provide acceptable levels of inflated performance in the areas of comfort, ride, handling, and adequate deflated mobility. Run-flat tires share these same basic design objectives:

1. Minimize the difference between run-flat tires and conventional tires when the tires are inflated.
2. Enhance the handling and riding capabilities of run-flat tires when inflated.
3. Provide acceptable handling when run-flat tires have zero pressure on various vehicles.
4. Enhance low-pressure and zero-pressure bead retention on run-flat tires.
5. Provide sufficient zero-pressure durability so the vehicle can be driven a reasonable distance to a repair facility.

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Run-Flat Tires with Sidewall Reinforcements

One of the most important requirements for run-flat tires is bead retention when running with low or zero pressure. Run-flat tires have improved beads to meet this requirement (Figure 4-16). Some run-flat tires have sidewall reinforcements that may be manufactured

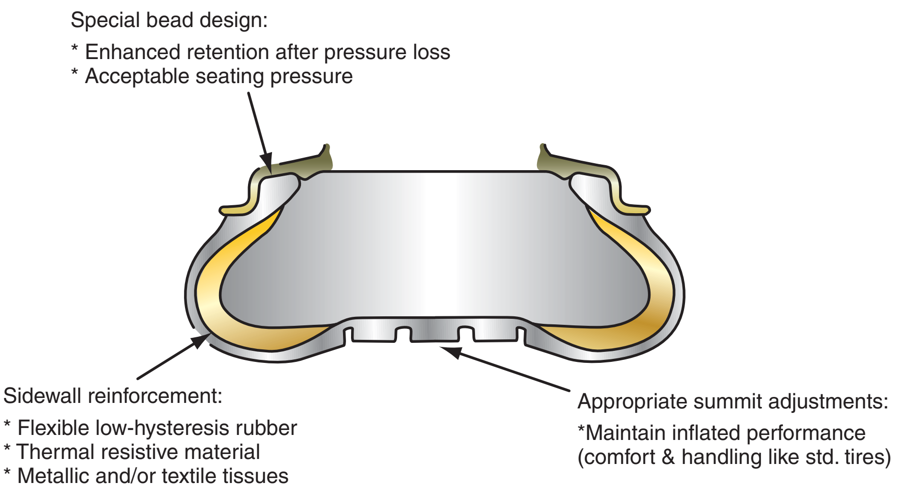
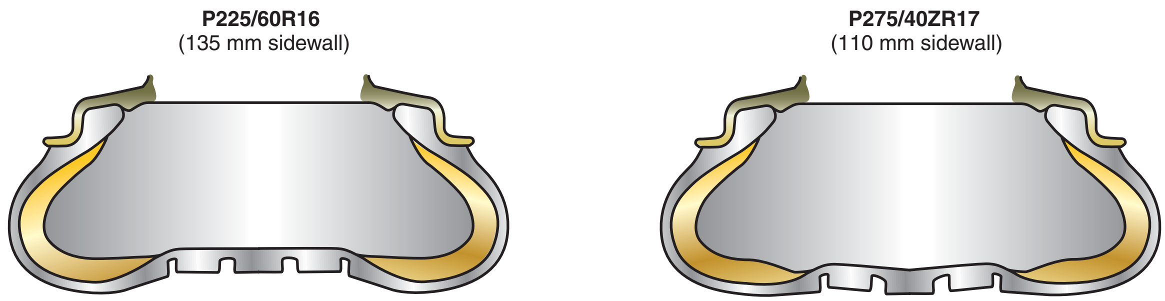


FIGURE 4-16 **Run-flat tire with sidewall reinforcement.**



Representative situation:
* Zero pressure 600 kg
* Front-wheel-drive luxury vehicle
* 89 km of zero-pressure durability at 80 km/h

Representative situation:
* Zero pressure 400 kg
* Rear-wheel-drive high-performance vehicle
* 300 km of zero-pressure durability at 89 km/h

FIGURE 4-17 **Run-flat tire zero-pressure durability.**

from flexible, low-hysteresis rubber, thermal resistive materials, or metallic and/or textile tissues. Run-flat tires with a high aspect ratio require increased sidewall stiffness compared to run-flat tires with a low aspect ratio. Because of these sidewall reinforcements, run-flat tires are 20 to 40 percent stiffer compared to conventional tires. Therefore, run-flat tires may increase ride harshness and vertical firmness especially when the tire strikes a large road irregularity. This increase in ride harshness is not as noticeable when the tire contacts a smaller road irregularity. The increased stiffness in run-flat tires usually provides a small improvement in vehicle handling.

Run-flat tires with a low aspect ratio usually have the same or less rolling resistance compared to equivalent-size conventional tires. Because run-flat tires with a high aspect ratio have increased sidewall stiffness, these tires tend to have increased rolling resistance compared to conventional tires.

CAUTION:
On a vehicle with PAX tires as original equipment, conventional tires and rims should not be substituted for the PAX tires and rims. This action will decrease ride quality and vehicle steering characteristics.

In moderate cornering and lane-change maneuvers, a run-flat tire with zero pressure provides a slight decrease in vehicle handling. The key word in the previous sentence is moderate. Run-flat tires are used with a tire pressure monitoring system, which has a warning light in the instrument panel to inform the driver when one tire has low pressure. Once the low tire pressure warning light is illuminated with the engine running, the driver should avoid high-speed driving and high-speed cornering, because run-flat tires provide reduced handling capabilities during high-speed cornering.

The zero-pressure durability of a run-flat tire varies depending on the vehicle weight, atmospheric temperature, and the tire aspect ratio. For example, a run-flat tire with a 40 aspect ratio supporting 880 lb (400 kg) provides 186 mi (300 km) of driving at 55 mph (89 km/h) (Figure 4-17). A run-flat tire with a 60 aspect ratio supporting 1,322 lb (600 kg) provides 50 mi (80 km) of driving at 55 mph (89 km/h).

Run-Flat Tires with Support Ring

Michelin PAX run-flat tires were first introduced in 1998. PAX run-flat tires are installed as original equipment on Honda Odessy, Nissan Quest, and Acura RL models, beginning in 2005 model year. PAX tires were introduced as original equipment on some European cars, beginning in 2002. The letters "PAX" translate to the values of peace of mind, safety, and the future.

CAUTION:
Using conventional tire changers that do not have PAX capabilities on PAX run-flat tires and rims may damage the tire and rim.

The run-flat tires in the PAX system have a flexible support ring mounted on a special rim to support the tire if deflation occurs. PAX tires do not have a stiffer sidewall, and so they provide excellent ride quality. When PAX tires are installed on a vehicle as original equipment, all the suspension system components such as springs and shock absorbers are engineered to go with the PAX tires.

PAX run-flat tire have a vertical, mechanical locking bead system that "latches" the bead to the rim. The outer tire bead has a smaller diameter compared with the inside tire

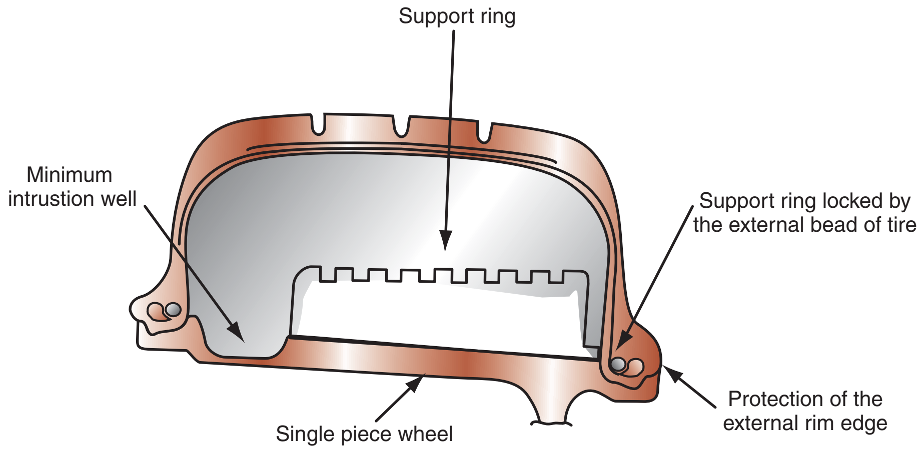


FIGURE 4-18 **Run-flat tire with support ring.**

bead. Therefore, the outer edge of the rim has a smaller diameter compared with the inner edge (Figure 4-18). When mounted on the rim, the tire beads lock into vertical grooves in the outer edges of the rim. The outer edges of the inner and outer tire beads extend slightly outside the wheel rim edges. This design helps protect the rim. PAX tires may be driven for 125 miles (201 km) at 55 mph (88 km/h) with zero air pressure. When mounting the tire on the rim, the tire is first positioned such that the tire beads are outside the rim. The outer (smaller diameter) bead is then mounted onto the rim, followed by the inner (larger diameter) bead. The disadvantages of this type of run-flat tire are the special rim that is required and the extra weight of the support ring. A tire pressure monitoring system is used with this type of run-flat tire.

TIRE PRESSURE MONITORING SYSTEMS

The Transportation Recall Enhancement Accountability and Documentation Act passed by the U.S. government in October 2000 requires all new vehicles to have tire pressure monitoring systems no later than the 2006 model year. A tire pressure monitoring system illuminates a warning light in the instrument panel to inform the driver if one tire has low pressure; some systems also alert the driver if tire temperature is excessive.

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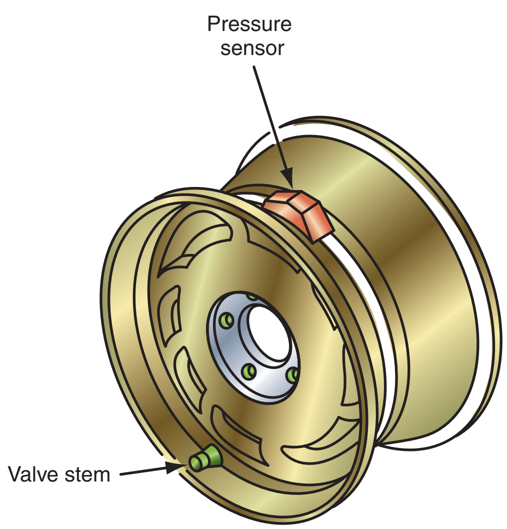
Some tire pressure monitoring systems have a sensor strapped in the dropwell on each rim (Figure 4-19). These sensors must be mounted on the rim directly opposite to the valve



Location	Color code
Right front	Blue
Left front	Green
Right rear	Orange
Left rear	Yellow

WARNING: Pressure sensor inside tire. Avoid contacting sensor with tire changing equipment tools or tire bead.

Service note: Pressure sensor must be mounted directly across from valve stem.

FIGURE 4-19 **Tire pressure sensor.**

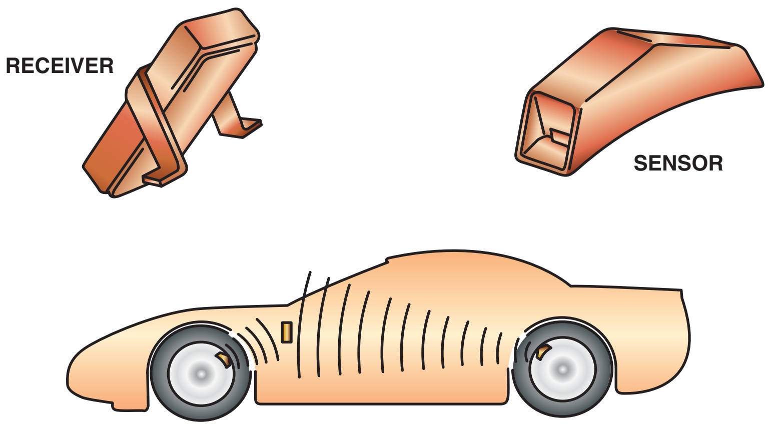


FIGURE 4-20 **Receiver in tire pressure monitoring system.**

stem. Other tire pressure monitoring systems have a sensor mounted on top of each valve stem in place of the valve cap. Regardless of the sensor's mounting location, it transmits radio frequency (RF) signals. These RF signals will change if any tire is underinflated a specific amount. The RF signals are sent to a receiver that is usually mounted under the dash (Figure 4-20). On some systems the receiver illuminates the low tire pressure warning light in the instrument panel if the pressure in any tire drops below 25 psi (172 kPa). On other systems the tire pressure warning light is illuminated with a smaller reduction in tire pressure.

Some tire pressure monitoring systems provide continuous monitoring with the vehicle stopped and the ignition switch on. Other systems will not monitor tire pressure until the vehicle is moving above a specific speed such as 25 mph (40 km/h). Some tire pressure monitoring systems have two warning lights: the low/flat tire warning light informs the driver regarding low tire pressure, and the service low tire pressure warning system (LTPWS) warning light informs the driver if there is a defect in the system (Figure 4-21). On some vehicles the low tire pressure receiver is connected to the data link connector (DLC) under the dash. A scan tool may be connected to the DLC to diagnose the tire pressure monitoring system. If a defect occurs in the system, a diagnostic trouble code (DTC) is stored in the receiver memory. A scan tool may be connected to the DLC to obtain the DTCs from the receiver.

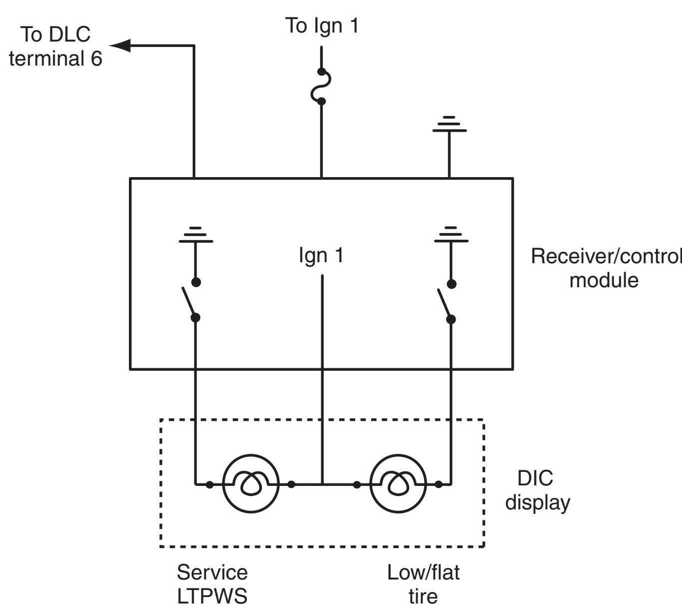


FIGURE 4-21 **Warning lights in tire pressure monitoring system.**

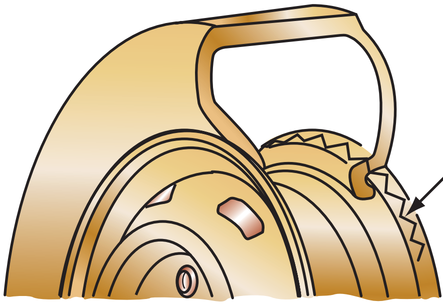


FIGURE 4-22 **Antenna in a tire sidewall.**

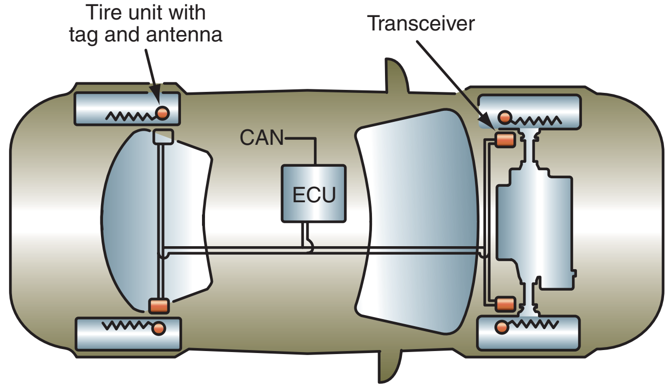


FIGURE 4-23 **Transceivers and ECU in a tire pressure monitoring system.**

Other tire pressure monitoring systems use the wheel speed sensor signals on four-channel antilock brake systems (ABS) to detect low tire pressure. A tire with low air pressure has a smaller diameter, and the wheel speed sensor generates a higher frequency signal.

Some tire pressure monitoring systems have a miniature pressure sensor and computer chip about the size of a watch battery. This sensor and chip assembly is imbedded in the tire. The pressure sensor senses the actual tire pressure and sends voltage signals in relation to the tire pressure to a transceiver via a 360° circumferential antenna mounted in the tire sidewall close to the rim (Figure 4-22). A transceiver is mounted in each wheel well. The pressure sensor and computer chip do not require a battery, because they receive energy from the transceiver-generated field. Each transceiver is connected by data links to a central electronic control unit (ECU) (Figure 4-23). The transceivers relay voltage signals from the pressure sensors to the ECU. The computer chip calculates the recommended tire pressure based on data such as air temperature, tire pressure, and vehicle speed. Vehicle speed information is transmitted via data links from the powertrain control module (PCM) to the ECU. If a low tire pressure signal is received by the ECU, the instrument panel displays a warning message together with a calculated number of miles of safe travel.

Tire Pressure Monitoring Systems (TPMS) with Valve Stem Sensors

Most current TPMS have pressure sensors that are attached to each valve stem inside the tire, and these sensors require a battery (Figure 4-24). Average battery life is approximately 10 years. A retention nut is threaded onto the valve stem on the outside of the wheel rim, and a sealing grommet is positioned between this nut and the rim (Figure 4-25). The internal threads on the retention nut are positioned near the bottom of the nut, and matching threads are located near the bottom end of the valve stem. A nickel-plated valve core is threaded into the internal threads in the valve stem, and a special valve cap is threaded onto the external threads at the top of the valve stem.

Many vehicles have a TPMS sensor in the spare tire. The valve stem acts as a radio antenna, and the TPMS module is the receiver. Each sensor transmits radio signals to the TPMS module every 60 seconds. On some SUVs the TPMS module is located behind the right-hand C pillar. The TPMS module compares the data from each tire pressure sensor to the low tire pressure limits. When the TPMS module determines that any of the five tires has a pressure below the specified pressure, this module sends voltage signals through the data links to the vehicle message center. When the message center receives voltage signals indicating low pressure in one or more tires, a warning message is displayed in the message

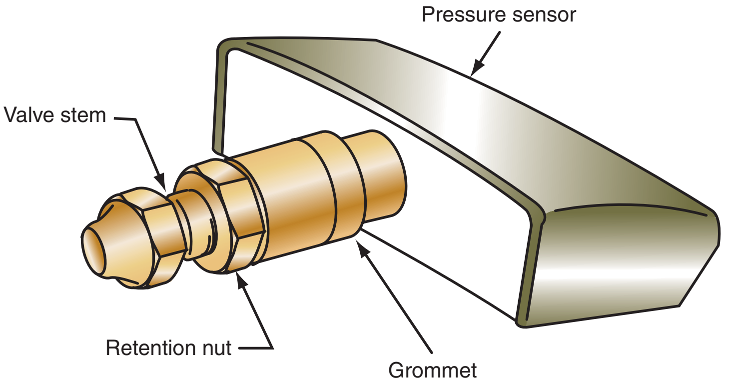


FIGURE 4-24 **Tire pressure sensor mounted on the valve stem.**

FIGURE 4-25 **Tire pressure sensor retention nut, valve cap, valve core, and grommet.**

center, and the TPMS warning light is illuminated. The possible messages related to the TPMS are:

1. WARNING TIRE VERY LOW – On some systems this message is displayed if any tire has less than 25 psi pressure. An audible warning chime is heard when this message is displayed, and the TPMS warning light is illuminated.
2. CHECK TIRE PRESSURE – On some systems this message is displayed if any tire has less than 30 psi pressure. An audible warning chime is heard when this message is displayed, and the TPMS warning light is illuminated.
3. TIRE PRESSURE SENSOR FAULT – This message is displayed if one or more sensors are malfunctioning. If this message is displayed, the TPMS warning light flashes for 20 seconds.
4. TIRE PRESSURE MONITOR FAULT – This message is displayed if the TPMS module is defective or if all four sensors have failed. The TPMS warning light flashes for 20 seconds when this message is displayed.

Some TPMS have the capability to sense a loss or an increase in tire pressure, and these systems also allow the driver to display the individual tire pressures and their locations on the driver information center (DIC) while the vehicle is being driven. This type of TPMS has conventional radio frequency–transmitting pressure sensors in each of the four valve stems. These sensors transmit signals to the antenna module, dash integration module (DIM), instrument panel cluster (IPC), and the DIC via the serial data circuit. The sensor's pressure accuracy from +14°F to +158°F (−10°C to +70°C) is plus or minus 1 psi (7 kPa).

When the vehicle speed is less than 20 mph (32 km/h), the system remains in the stationary mode. In this mode, the sensors transmit data every 60 minutes to provide longer sensor battery life. When the vehicle speed is 20 mph (32 km/h) or greater, centrifugal force closes a roll switch in each sensor, and this action causes the sensors to enter the drive mode in which the sensors transmit signals every 60 seconds. The antenna module receives and translates each sensor signal into sensor presence, sensor mode, and tire pressure. The temperature and speed ratings of the TPMS system vary depending on the vehicle manufacturer. Always consult the vehicle manufacturer's specifications. The antenna module then transmits this information from each sensor to the DIC via the serial data circuit. The DIC displays an overhead view of the vehicle in which tire locations and pressures are displayed. If the TPMS senses a specific pressure gain or loss in any tire, a CHECK TIRE PRESSURE warning message is displayed on the DIC, and the low tire pressure warning indicator is illuminated in the IPC. Any defect in the TPMS system causes a SERVICE TIRE MONITOR warning message to be displayed on the DIC.

TPMS with Electronic Vehicle Information Center (EVIC) Display

Some TPMS provide graphic tire pressure displays and warning messages on an EVIC display in the instrument panel. These systems may have 4-tire or 5-tire monitoring capabilities. A TPMS with 5-tire monitoring capabilities also monitors the spare tire. These systems have valve stem sensors that broadcast tire pressure once per minute when the vehicle is moving at 25 mph (40 km/h) or faster. If the vehicle has a 5-tire TPMS, the sensor in the spare tire transmits a signal every hour. Each valve stem sensor transmits a unique code so the EVIC module can determine the location of the sensor. If the wheels are rotated on the vehicle, or the spare tire and wheel are installed on the vehicle, the EVIC must be reprogrammed to recognize the new wheel and tire locations.

This type of TPMS provides a warning display in the EVIC if the tire pressure drops below a specific value or increases above a certain threshold. Typically, if the tire pressure in any tire decreases below 25 psi (172 kPa), the EVIC requests a chime warning, displays a LOW PRESSURE message, and indicates the location of the tire with low pressure. If the pressure in any tire exceeds 45 psi (310 kPa), the EVIC requests a chime warning and displays HIGH PRESSURE while indicating the location of the tire with high pressure. After a few seconds the EVIC reverts to a blinking display of the tire pressure. This blinking display continues for the entire ignition cycle or until an EVIC button is pressed. When an EVIC button is pressed, the blinking display returns after 60 seconds without the chime warning. If high or low pressure is detected in the spare tire on a 5-tire system, SPARE HIGH PRESSURE or SPARE LOW PRESSURE appears on the EVIC display for 60 seconds during each ignition cycle.

Tire Contact Area

The **tire contact area** refers to the area of the tire that is in contact with the road surface when the tire is supporting the vehicle weight. The **tire free diameter** is the distance of a horizontal line through the center of the spindle and wheel to the outer edges of the tread. The **tire rolling diameter** is the distance of a vertical straight line through the center of the spindle to the outer edges of the tread when the tire is supporting the vehicle weight. The rolling diameter is always less than the free diameter. The difference between the free diameter and the rolling diameter is referred to as deflection. Tire tread grooves take up excess rubber and prevent scrubbing as the tire deflects in the contact area. The rolling diameter, free diameter, and contact area are shown in Figure 4-26.

Tire deflection is the difference between the free diameter and the rolling diameter of the tire.

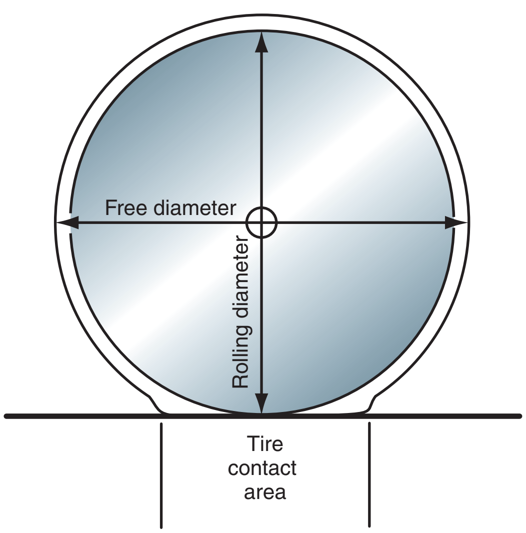


FIGURE 4-26 **Tire rolling diameter, free diameter, and contact area.**

Tire Placard and Inflation Pressure

Tire pressure is the amount of air pressure in the tire.

The vehicle weight is supported by the correct air pressure exerted evenly against all the interior tire surface, which produces tension in the tire carcass. Therefore, **tire pressure** is extremely important. Underinflation decreases the rolling diameter and increases the contact area, which results in excessive sidewall flexing and tread wear. Overinflation decreases the contact area, increases the rolling diameter, and stiffens the tire. This action results in excessive wear on the center of the tread. Tire pressure should be checked when the tires are cool. Since tire pressure normally increases at high tire temperatures, air pressure should not be released from hot tires. Excessive heat buildup in a tire may be caused by underinflation. This condition may lead to severe tire damage.

Author's Note: There are many causes of excessive tire tread wear such as improper wheel balance or alignment. However, it has been my experience that one of the most common causes of excessive tire tread wear is improper inflation pressure. Many vehicle owners or drivers do not check tire pressures regularly.

On many vehicles, the **tire placard** is permanently attached to the rear face of the driver's door. This placard provides tire information such as maximum vehicle load; tire size, including spare; and cold inflation pressure, including spare (Figure 4-27).

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Tire pressure is carefully calculated by the vehicle manufacturer to provide satisfactory tread life, handling, ride, and load-carrying capacity. Most vehicle manufacturers recommend that tire pressures be checked cold once a month or prior to any extended trip. The manufacturer considers the tires to be cold after the vehicle has sat for three hours, or when the vehicle has been driven less than one mile. The tires should be inflated to the pressure indicated on the tire placard. Tire pressures may be listed in metric or English system values. Conversion charts provide pressures in either of these systems (Table 4-3).

Nitrogen Tire Inflation

Some shops are presently equipped with **nitrogen tire inflation** equipment. When tires are inflated with compressed air, the air slowly passes through the tire walls and tread. Tires inflated with compressed air can lose as much as 12 psi in a 6-month period. When tire inflation pressure is lower than specified, tire tread wear is increased, while fuel economy and vehicle stability are decreased.

Nitrogen molecules are considerably larger than air molecules (Figure 4-28). Therefore, when a tire is inflated with nitrogen, the nitrogen passes through the tire walls and tread more slowly when compared with air. When tires are inflated with nitrogen, the tire inflation

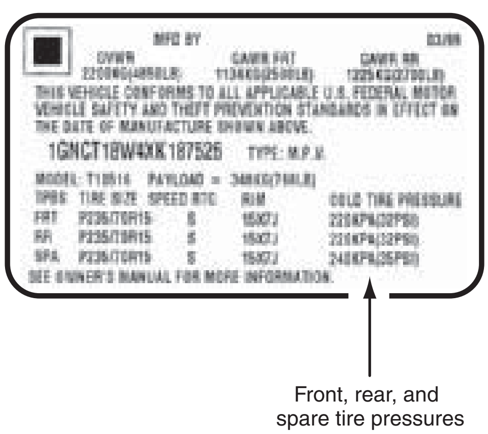

FIGURE 4-27 **Tire placard.**

TABLE 4-3 **TIRE INFLATION PRESSURE CONVERSION CHART**

Inflation Pressure Conversion Chart
(Kilopascals to PSI)

kPa	psi	kPa	psi
140	20	215	31
145	21	220	32
155	22	230	33
160	23	235	34
165	24	240	35
170	25	250	36
180	36	275	40
185	37	310	45
190	38	345	50
200	39	380	55
205	30	415	60
Conversion: 6.9 kPa=1 psi			

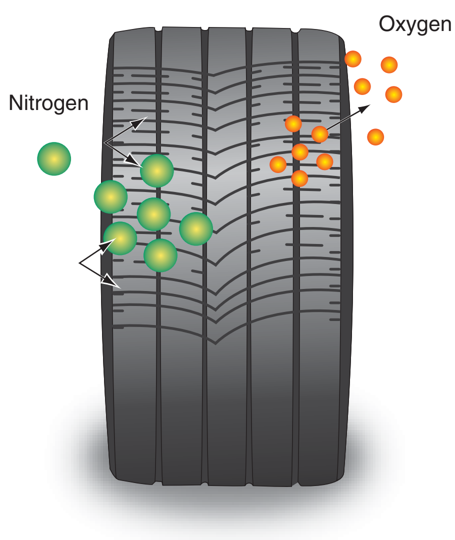

FIGURE 4-28 **Oxygen and nitrogen leakage through tire walls and tread.**

pressure remains more stable over a longer time period, which provides reduced tire tread wear, improved fuel economy, and increased vehicle stability. Another benefit from using nitrogen to inflate tires is reduced aluminum rim corrosion because the nitrogen does not contain any oxygen. When tires are filled with air, the oxygen in the air tends to react with the aluminum in the rims to cause corrosion.

Tire Motion Forces

When a vehicle is in motion, wheel rotation subjects the tires to centrifugal force. The tires are also subjected to accelerating and decelerating forces because of their path of travel. If a vehicle is traveling at 55 miles per hour (mph), or 88.5 kilometers per hour (km/h), the part of the tire exactly fore and aft of the spindle is also traveling at 55 mph (88.5 km/h). At the exact top of the tire, the tire speed is 110 mph (177 km/h). The tire speed actually drops to zero at the exact bottom of the tire where the arc of deceleration ends and the arc of acceleration

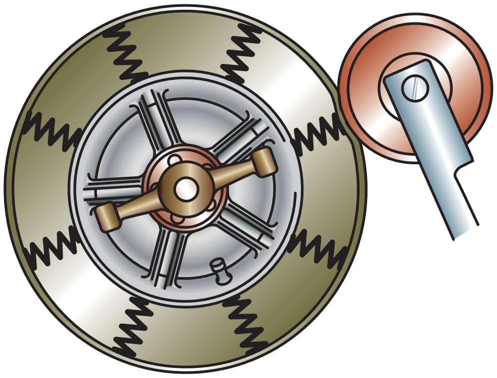

FIGURE 4-29 **The roller on some wheel balancers senses road force variation.**

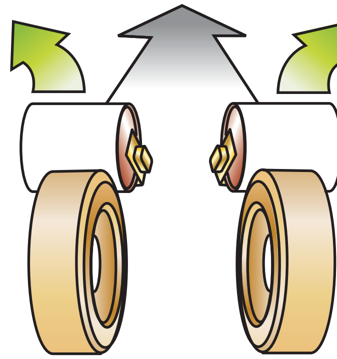

FIGURE 4-30 **The roller on some wheel balancers senses concentricity.**

begins. Since the tires are subjected to strong acceleration and deceleration forces, the tire construction must be uniform. A soft spot in a tire will deflect farther than the surrounding area, and this area will be subjected to rapid wear as it strikes the road surface.

Tires must have equal stiffness in the sidewalls around the tire. If a tire does not have equal stiffness in all areas around the tire sidewalls, it may cause a vibration when driving. This vibration is called **road force variation** and produces a vibration similar to the vibration caused by improper wheel and tire balance. Modern wheel balancers have a roller that is forced against the tire tread during the balance procedure, and this type of balancer detects road force variation (Figure 4-29).

Road force variation is a condition that occurs when tire sidewalls do not have equal stiffness around the complete area of the sidewalls.

Tires must be manufactured so the cords are concentric with the center of the tire. Tire conicity is a term used to describe a tire in which the cords are off-center in relation to the tire center. If the tire cords are not concentric with the tire center, the tire may cause a steering pull condition when driving. Modern wheel balancers use a roller pressed against the tire tread to detect conicity during the balance procedure (Figure 4-30).

Wheel Rims

Many **wheel rims** are manufactured from stamped or pressed steel discs that are riveted or welded together to form the circular rim. Currently, less than 50 percent of the wheel rims installed by the original equipment manufacturers (OEMs) are stamped steel type. The rim offset is the distance between the rim centerline and the mounting face of the disc (Figure 4-31). If a rim is designed with positive offset, the rim centerline is inboard of the mounting face. The rim with negative offset has the centerline outboard of the mounting face. The rim offset affects front suspension loading and operation.

Wheel rims are circular devices on which the tires are mounted. Wheel rims are bolted to the wheel hubs or axles.

A large hole in the center of the rim fits over a flange on the mounting surface. The rim has a small hole for the valve stem. The wheel stud mounting holes in the rim are tapered to match the taper on the wheel nuts. Some late model Ford trucks have non-self-centering wheel nuts. On these nuts, a swivel washer is attached to the inner side of each nut (Figure 4-32). When the wheel and nuts are installed, the flat side of the swivel nut fits against the wheel rim. The wheels are hub-centered, and an O-ring mounted on the hub provides improved wheel centering (Figure 4-33). If this O-ring is missing or damaged, the wheel may not be properly centered, and this condition results in wheel vibrations. The O-ring also provides a seal to prevent corrosion.

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Cars and light-duty trucks have four, five, six, or eight mounting stud openings and an equal number of matching studs in the hub or axle (Figure 4-34). The number of wheel studs depends on the vehicle weight and load. Heavier vehicles and/or increased vehicle load usually require more wheel mounting studs. The lug nuts retain the wheel on the hub or axle. These nuts usually have a taper on the inner side of the nuts, and this taper fits against a matching taper on the wheel stud openings. These tapers on the nuts and wheel openings

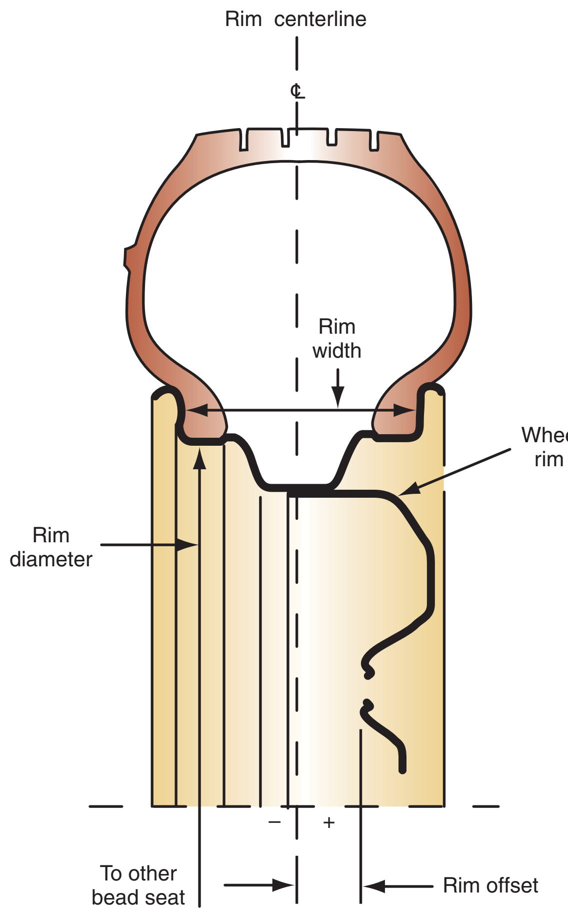

FIGURE 4-31 **Wheel rim design.**

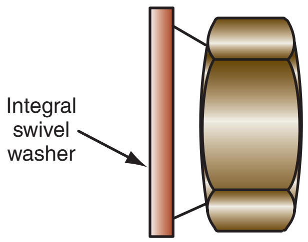

FIGURE 4-32 **Non-self-centering wheel nut design.**

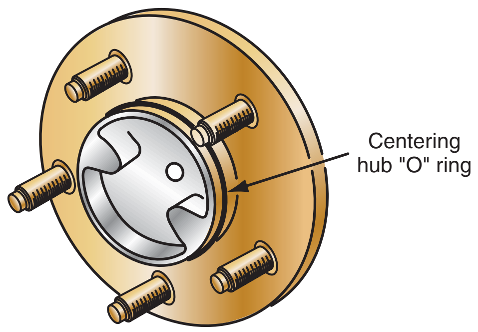

FIGURE 4-33 **Hub O-ring that provides wheel centering.**

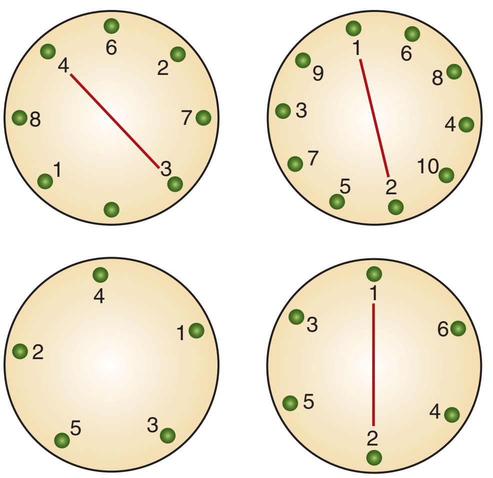
FIGURE 4-34 **Wheel stud configurations.**

center the wheel on the hub or axle. Wheel stud openings are listed by the number of studs and the circle through the stud centers. For example, if wheel openings are listed as 5– 4.5, there are five wheel studs and stud openings, and the centers of the wheel studs and wheel openings are on a 4.5 in. (11.4 cm) circle. If a wheel has an even number of studs, measure the distance between opposite stud centers to check the stud position and wheel circle. On a five-bolt wheel, measure the distance between two adjacent stud centers. The specified distances between adjacent wheel stud centers and the corresponding wheel circles are the following:

4.5 in. wheel circle	2.64 in. between adjacent stud centers
4.75 in. wheel circle	2.79 in. between adjacent stud centers

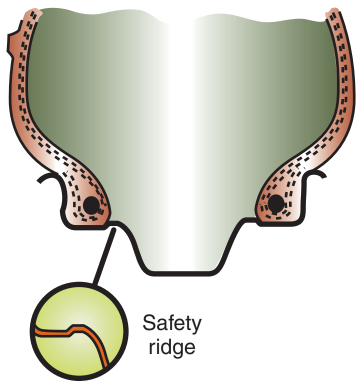

FIGURE 4-35 **Wheel rim with drop center and safety ridges.**

5.0 in. wheel circle	2.93 in. between adjacent stud centers
5.5 in wheel circle	3.23 in. between adjacent stud centers

Templates are available to measure the stud position on wheels that do not have an even number of studs.

The width of the wheel is measured between the vertical bead seats on the rim flanges. Rim diameter is the distance between the horizontal part of the bead seats measured through the rim center bottom. A drop center in the rim makes tire changing easier (Figure 4-35). Rims have safety ridges behind the tire bead locations, which help prevent the beads from moving into the drop center area if the tire blows out. If the tire blows out and a bead enters the drop center area, the tire may come off the wheel.

Cast aluminum wheels are commonly used on many vehicles by OEMs. These wheels may be polished, chromed, or painted. A cast aluminum wheel costs about twice as much as a stamped steel wheel.

Forged aluminum wheels are installed on some vehicles. They are more durable than cast aluminum wheels and have a bright finish. Forged aluminum wheels are used on heavy-load applications such as trucks. Some expensive sports cars are also equipped with forged aluminum wheels. A forged aluminum wheel is lighter than a steel wheel, but the cost of a forged aluminum wheel is considerably higher than a stamped steel or cast aluminum wheel.

Some vehicles are equipped with pressure-cast aluminum wheels that are designed to be chrome plated. Pressure-cast wheels may also be called squeeze-cast wheels. During the manufacture of a pressure-cast wheel, the molten metal is squeezed under pressure into the mold. This action squeezes all the air out of the metal and reduces the metal porosity, which provides an improved substrate for chrome plating. The chrome plating increases the cost of the pressure-cast aluminum wheel so it is considerably more expensive than other types of wheels.

Magnesium alloy wheels may be called "mag" wheels.

Race cars may be equipped with **magnesium alloy wheels**, which are lighter than either steel or aluminum wheels.

Replacement wheel rims must be the same as the original equipment wheels in load capacity, offset, width, diameter, and mounting configuration. An incorrect wheel can affect tire life, steering quality, wheel bearing life, vehicle ground clearance, tire clearance, and speedometer/ odometer calibrations.

Static Wheel Balance Theory

Static balance refers to the balance of a wheel in the stationary position.

When a tire-and-wheel assembly has proper **static balance**, it has the weight equally distributed around its axis of rotation, and gravity will not force it to rotate from its rest position. If a vehicle is raised off the floor and a wheel is rotated in 120° intervals, a statically balanced wheel will remain stationary at each interval. When a wheel and tire are statically unbalanced, the tire

has a heavy portion at one location. The force of gravity acting on this heavy portion will cause the wheel to rotate until the heavy portion is located near the bottom of the tire (Figure 4-36).

Results of Static Unbalance

Centrifugal force may be defined as the force that tends to move a rotating mass away from its axis of rotation. As we have explained previously, a tire and wheel are subjected to very strong acceleration and deceleration forces when a vehicle is in motion. The heavy portion of a statically unbalanced wheel is influenced by centrifugal force. This influence attempts to move the heavy spot on a tangent line away from the wheel axis. This action tends to lift the wheel assembly off the road surface (Figure 4-37).

The wheel-lifting action caused by static unbalance may be referred to as **wheel tramp** (Figure 4-38). Wheel tramp action allows the tire to slip momentarily when it is lifted vertically. When the wheel and tire move downward as the heavy spot decelerates, the tire strikes the road surface with a pounding action. This repeated slipping and pounding action causes severe tire scuffing and cupping (Figure 4-39).

Wheel tramp may be defined as rapid upward and downward wheel and tire oscillations.

The vertical wheel motion from static unbalance is transferred to the suspension system and then absorbed by the chassis and body. This action causes rapid wear on suspension and steering components. The wheel tramp action resulting from static unbalance is also transmitted to the passenger compartment, which causes passenger discomfort and driver fatigue.

When a vehicle is traveling at normal highway cruising speed, the average wheel speed is 850 revolutions per minute (rpm). A statically unbalanced tire-and-wheel assembly is an uncontrolled mass of weight in motion. When a vehicle is traveling at 60 mph (97 km/h) and a tire has 2 ounces (oz), or 57 grams (g), of static unbalance, the resultant pounding force is approximately 15 pounds (lb), or 6.8 kilograms (kg), against the road surface.

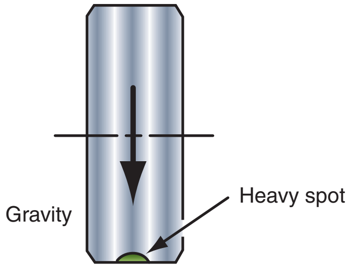

FIGURE 4-36 Static wheel unbalance.

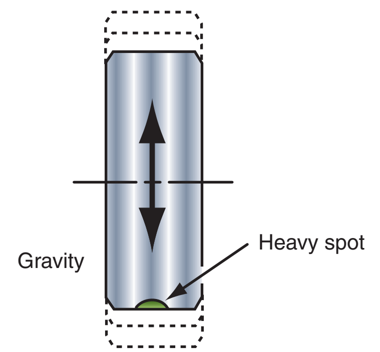

FIGURE 4-37 Effects of static unbalance.

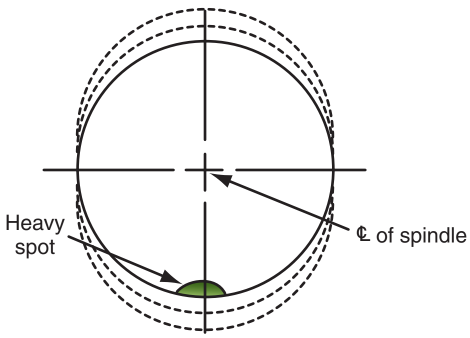

FIGURE 4-38 Wheel tramp.

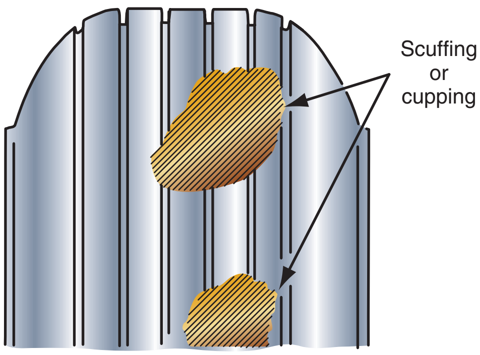

FIGURE 4-39 Cupping tire wear caused by static unbalance.

Dynamic Wheel Balance Theory

Dynamic balance refers to the balance of a wheel in motion.

When a tire-and-wheel assembly has correct **dynamic balance**, the weight of the assembly is distributed equally on both sides of the wheel center viewed from the front. Dynamic wheel balance may be explained by dividing the tire into four sections (Figure 4-40). In Figure 4-40, if sections A and C have the same weight and sections B and D also have the same weight, the tire has proper dynamic balance. If a tire has dynamic unbalance, section D may have a heavy spot; thus, sections B and D have different weights (Figure 4-41).

From our discussion of dynamic balance, we can understand that a tire-and-wheel assembly may be in static balance, but have dynamic unbalance. Therefore, wheels must be in balance statically and dynamically.

Results of Dynamic Wheel Unbalance

Wheel shimmy may be defined as rapid inward and outward oscillations of a front wheel.

When a dynamically unbalanced wheel is rotating, centrifugal force moves the heavy spot toward the tire centerline. The centerline of the heavy spot arc is at a 90° angle to the spindle. This action turns the true centerline of the left front wheel inward when the heavy spot is at the rear of the wheel (Figure 4-42). When the wheel rotates until the heavy spot is at the front of the wheel, the heavy spot movement turns the left front wheel outward (Figure 4-43).

From these explanations, we can understand that dynamic wheel unbalance causes lateral wheel shake, or shimmy (Figure 4-44). This action causes steering wheel oscillations at medium and high speeds with resultant driver fatigue and passenger discomfort. Wheel shimmy and steering wheel oscillations also cause unstable directional control of the vehicle.

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Earlier in this chapter, when discussing wheel rotation, we mentioned that a tire stops momentarily where it contacts the road surface. A wheel with dynamic unbalance is forced to pivot on the contact area, which results in excessive tire scuffing and wear. Dynamic wheel unbalance causes premature wear on steering linkage and suspension components. Therefore, dynamic wheel balance is extremely important to provide normal tire life, reduce steering and suspension component wear, increase directional control, and decrease driver fatigue. The main purposes of proper wheel balance may be summarized as follows:

1. Maintains normal tire tread life.
2. Provides extended life of suspension and steering components.
3. Helps provide directional control of the vehicle.

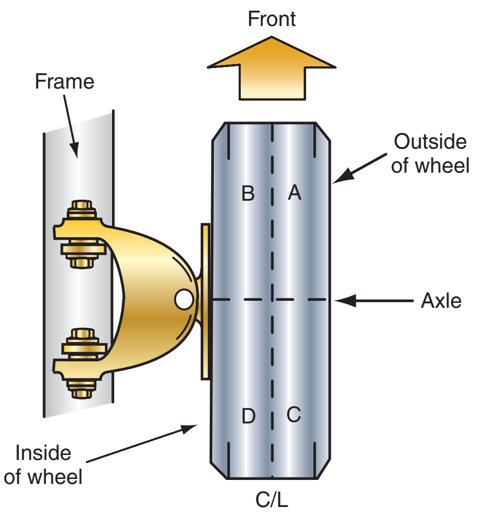

FIGURE 4-40 **Dynamic wheel balance theory.**

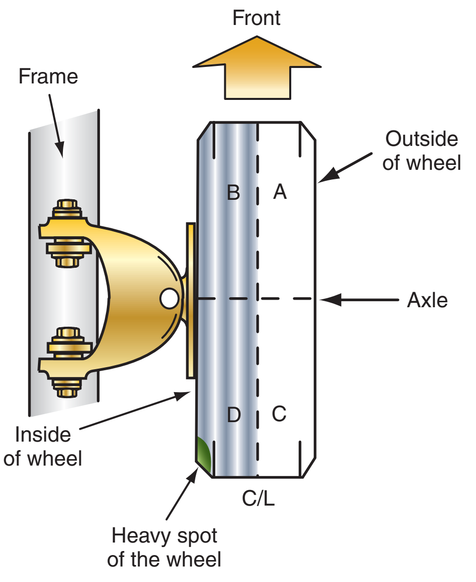

FIGURE 4-41 **Dynamic wheel unbalance.**

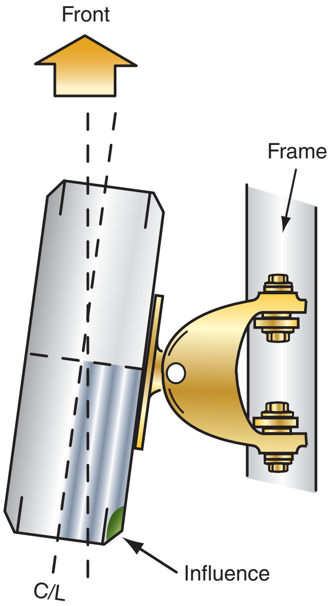

FIGURE 4-42 **Dynamic wheel unbalance with heavy spot at the rear of the left front tire.**

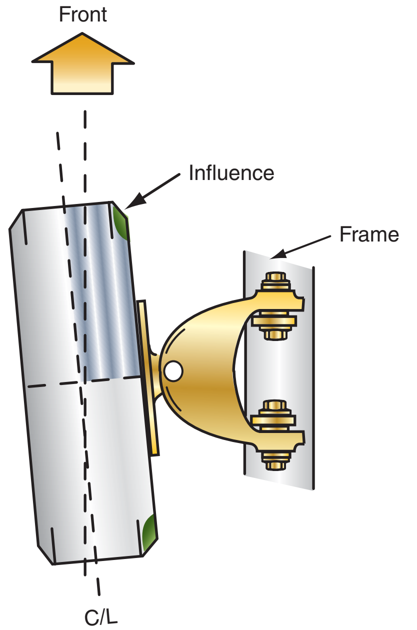

FIGURE 4-43 **Dynamic wheel unbalance with heavy spot at the front of the left front tire.**

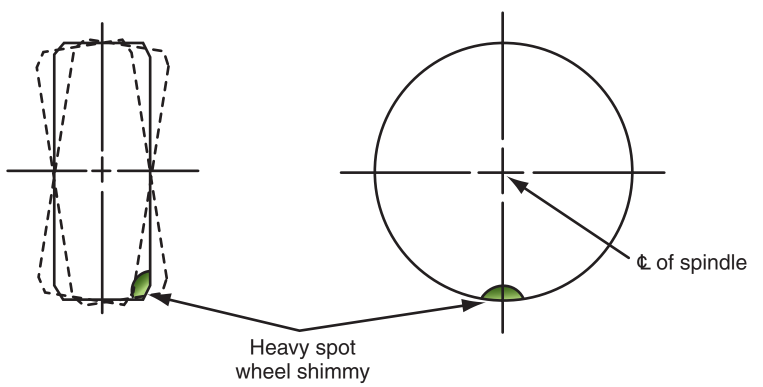

FIGURE 4-44 **Dynamic wheel unbalance causes wheel shimmy.**

4. Reduces driver fatigue.
5. Increases passenger comfort.
6. Helps maintain the life of body and chassis components.

Noise, Vibration, Harshness

Original equipment manufacturers (OEMs) have made significant improvements in reducing vehicle noise, vibration, and harshness (NVH) because many customers prefer a quieter-running vehicle with reduced vibration and ride harshness. The suspension system plays a significant role in reducing NVH. Many of the suspension features described in this chapter are designed to reduce NVH. These features include track bars and braces, proper car riding height, hydraulic suspension system mounts, independent rear suspension systems, and large rubber insulating bushings on suspension system mountings.

However, the technician must understand that reducing NVH involves many mechanical and body/chassis components on the vehicle. For example, some vehicles have an optimized body structure, which is the major reason for reduced NVH. In this body design, lateral tie bars that connect the front longitudinal rails provide a stiffer front end. At the rear of the car, one-piece side rings with integral quarters eliminate rear pillar seams and provide a more precise door fit. The instrument panel and steering column are integrated solidly into the body structure by a cast magnesium beam. The door hinges are through-bolted and thick spacer blocks are installed on these bolts to provide a very solid door attachment. Because the entire body is stronger and more rigid, the suspension can provide excellent ride quality and steering control without having to compensate for unwanted body flexing. In addition, appropriate body cavities like the dash panel are filled with expandable baffles to eliminate noise. The five-layer noise buffer in the dash panel contains these materials:

1. Fiberglass insulation mat
2. Viscoelastic energy-absorbing layer
3. Double steel panel
4. Single one-piece dash mat

A cast foam floor carpet system reduces noise transmitted through the floor pan and wheel wells. The door pillar and rocker panel cavities contain over 20 noise blockers.

Many engine refinements reduce vibration. For example, many engines now have a deep skirt block with the main bearings bolted through the sides of the block and also vertically. Many engines now have cast oil pans and rocker covers rather than stamped steel components. The main bearing caps are contained in a one-piece casting on many engines to increase bottom end strength and reduce engine vibration. Some V-8 engines have a rubber intake manifold valley stuffer attached to the underside of the intake manifold to reduce vibration. Other vehicles have a slip yoke vibration damper mounted on the front of the drive shaft to reduce driveline vibration. Therefore, reducing NVH is a total vehicle concept.

Vibration Theory

Vibrations have these three elements:

1. Source—the cause of the vibration
2. Path—where the vibration travels through the vehicle
3. Responder—the component where the vibration is felt

For example, if the vehicle has an unbalanced tire, this is the vibration source. The vibration path is the steering and suspension system through which the vibration travels. The responder is the steering wheel because this component is where the customer feels the vibration (Figure 4-45). When diagnosing vibration problems, locate and correct the source of the vibration. In the previous example of the unbalanced tire, installing a rigid brace from the steering column to the instrument panel and chassis may reduce the vibration experienced by the customer, but this does not solve the problem. To eliminate the problem, also diagnose the unbalanced tire condition and then balance the tire-and-wheel assembly.

Vibration may also produce noise. If a vehicle has a broken or improperly positioned tail-pipe hanger that allows the tailpipe to contact the chassis, the customer may complain about a vibrating noise. The floor panel acts as a large speaker and amplifies the vibrating noise. The vibration path is through the exhaust system and chassis to the floor panel. The responder is the chassis and floor panel. In this case, after diagnosing the broken or improperly positioned tailpipe hanger, replace or reposition it so the vibration transfer path is eliminated.

A **cycle** begins and ends at the same point

Clamp a yardstick to a table top with 18 in (45 cm) hanging over the edge of the table (Figure 4-46). If the outer end of the yardstick is pulled upward or downward and then released, the end of the yardstick repeatedly vibrates up and down. Each vibration **cycle** begins at the

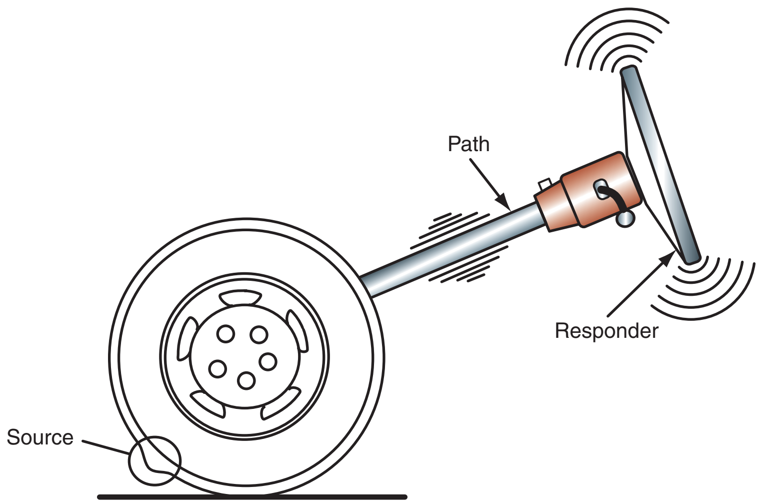

FIGURE 4-45 **Vibration source, path, and responder.**

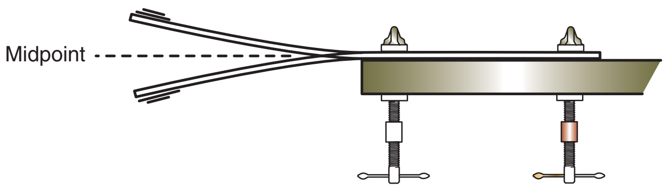

FIGURE 4-46 **Theory of vibration cycles.**

FIGURE 4-47 **Electronic vibration analyzer (EVA).**

midpoint with the yardstick straight. From this point, the vibration cycle continues to the lowest point of travel and then moves up through the midpoint to the highest point of travel. The vibration cycle then returns to the midpoint where it begins over again.

If the end of the vibrating yardstick completed 10 cycles per second, this is called the **frequency** of the vibration. To calculate the cycles per minute multiply the cycles per second by 60. In this example the $10 \times 60 = 600$ cycles per minute.

The **frequency** of a vibration is the number of cycles per second or cycles per minute.

If the yardstick is clamped to the table top with an 8 in (20 cm) overhang, the end of the yardstick will vibrate much faster when the end of the yardstick is pulled upward or downward. Under this condition, the end of the yardstick may vibrate at a frequency of 30 cycles per second or 1800 cycles per minute.

Many vehicle vibrations are caused by an out-of-balance rotating component or engine firing pulses improperly isolated from the passenger compartment. Customers usually complain about vibrations that are felt in the steering wheel, instrument panel, frame or chassis, or the front or rear seat.

Vehicle vibrations may be tested with an **electronic vibration analyzer (EVA)**. (Figure 4-47). The EVA has a vibration sensor that is mounted on the suspected vibration source. The EVA senses and records vibration cycles. A vibration cycle begins and ends at

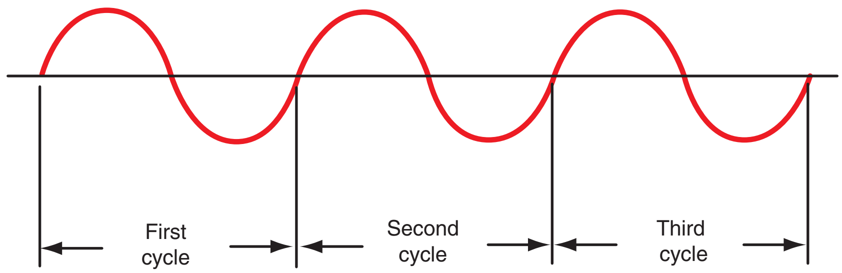

FIGURE 4-48 **Vibration cycles.**

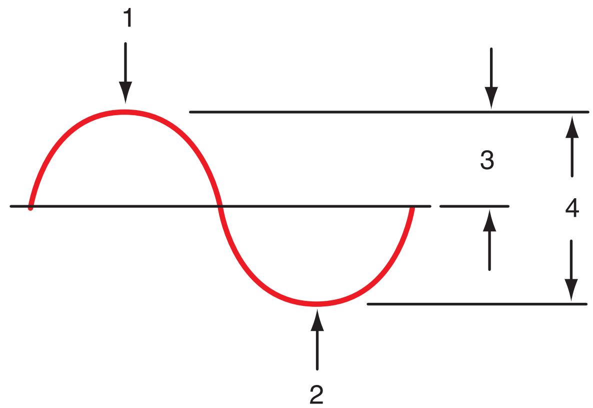

FIGURE 4-49 **Amplitude of vibration cycles.**

Natural vibration frequency is the frequency at which the object tends to vibrate.

Resonance is the point where the frequency of a vibration from a defective component intersects with the natural frequency of the component or system where the component is located.

the same point and is continually repeated (Figure 4-48). Cycles per second are measured in **Hertz (Hz)**, and the Hz may be multiplied by 60 to obtain the cycles per minute. The **amplitude** of a vibration is the maximum value of the varying vibration. In Figure 4-49, 1 represents the maximum amplitude, 2 is the minimum amplitude, 3 is the zero-to-peak amplitude, and 4 indicates the peak-to-peak amplitude. The vibration amplitude may vary with the rotating speed of a component. For example, if a tire-and-wheel assembly is unbalanced, the amplitude of the resulting vibrations increases with wheel speed.

All objects have **natural vibration frequencies**. The natural frequency of a front suspension system is 10 to 15 Hz. The suspension system design determines the natural frequency. The natural frequency of the suspension system is the same at all vehicle speeds.

The vibration frequency caused by an unbalanced tire-and-wheel assembly increases with wheel speed. When the vibration frequency caused by the wheel balance problem intersects with the natural frequency of the suspension system, the suspension system begins to vibrate. This intersection point is called the **resonance**.

Vibration Classifications and Terminology

Vibrations that can be felt are:

1. Shake
2. Roughness
3. Buzz
4. Tingling

Vibrations that result in noise may be classified as:

1. Boom
2. Moan or drone
3. Howl
4. Whine

Shake

A shake is a vibration with a low frequency of 5 to 20 Hz, and is sometimes experienced in the steering wheel, seat, or console. Customers may refer to shake as shimmy, wobble, shudder, waddle, or hop. Most cases of a shake vibration are caused by brake rotors and drums or unbalanced tire-and-wheel assemblies. These defects cause a shake-type vibration that is vehicle-speed sensitive. The engine, clutch, or transmission may cause a shake-type vibration that is engine-speed sensitive.

Roughness

Roughness is a vibration with a higher frequency of 20 to 50 Hz. Holding a jigsaw to cut a piece of wood produces a roughness-type vibration. A roughness vibration may be caused by a defective wheel bearing. Prior to causing a roughness vibration, the defective wheel bearing would cause a howl.

Buzz

A buzz has a faster frequency of 50 to 100 Hz. Holding a vibrator-type electric razor produces a feeling similar to a buzz vibration. This type of vibration is usually felt in the vehicle floor or the seat. A buzz-type vibration is usually caused by defects in the exhaust system hangers, A/C compressor, or the engine.

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Tingling

A tingling vibration has a very high frequency much like a pins-and-needles sensation. Customers may complain that a tingling-type vibration puts their hands and feet to sleep. A tingling vibration may be caused by improper drive shaft balance in a rear-wheel-drive vehicle.

Boom

A boom noise has a low frequency of 20 to 60 Hz. A boom-type vibration produces a noise similar to a bowling ball rolling down a bowling alley. A customer may describe a boom-type vibration as droning, growling, humming, rumbling, roaring, or moaning. A boom-type noise and vibration may be caused by engine backfiring resulting from ignition defects.

Moan or Drone

A moan or drone is a tone with a higher frequency of 60 to 120 Hz. A moan or drone produces a noise similar to a bumblebee in flight. Moan or drone may be caused by defects in the exhaust system or defective engine or transmission mounts.

Howl

A howl is a noise with frequency of 120 to 300 Hz, and this sound is much like the wind howling. A howling noise may be caused by worn differential bearings.

Whine

A whine is a high-pitched sound with a frequency of 300 to 500 Hz, and this sound is similar to a vacuum cleaner. A whine problem may be caused by meshing gears in the transmission of differential. When diagnosing vibration problems, the technician should match the vibration frequency to the rotating speed of a component, to help locate the component responsible for the vibration.

Terms to Know

All-season tires
Amplitude
Bead wire
Bead filler
Belt cover
Belted bias-ply tires
Bias-ply tires
Compact spare tires
Conicity
Cord plies
Dynamic balance
Electronic vibration analyzer Hertz
Hydroplaning
Liner
Load rating
Magnesium alloy wheels
Mud and snow tires
Natural vibration frequencies
Nitrogen tire inflation
Puncture sealing tires

Summary

Terms to Know

Radial-ply tires
Replacement tires
Resonance
Road force variation
Run-flat tires
Sidewalls
Speed rating
Static balance
Synthetic rubber
Temperature rating
Tire belts
Tire chains
Tire contact area
Tire free diameter
Tire performance criteria (TPC)
Tire placard
Tire pressure
Tire rolling diameter
Tire treads
Tire valve
Traction ratings
Tread wear ratings
Uniform Tire Quality Grading (UTQG) System
Wheel rims
Wheel tramp

- Tires are extremely important because they provide ride quality, support the vehicle weight, provide traction for the drive wheels, and contribute to steering quality and directional stability.
- Tires have many design features and are carefully engineered to meet specific driving requirements.
- Tires may be bias-ply, belted bias-ply, or radial belted design.
- Tire ratings provide information regarding tire type, section width, aspect ratio, construction type, rim diameter, load capacity, and speed rating.
- Numeric tire ratings provide information about tire type, aspect ratio, construction type, and rim diameter.
- The tire performance criteria (TPC) number represents that the tire meets the car manufacturer's performance standards for traction, endurance, dimensions, noise, handling, and rolling resistance.
- The Uniform Tire Quality Grading (UTQG) designation includes tread wear, traction, and temperature ratings.
- Replacement tires must be the same type and size as the original tires to maintain vehicle safety.
- Replacement tires must have the same ratings as the original tires to maintain vehicle safety.
- The tire placard provides valuable information regarding the tires on the vehicle.
- Tires are subjected to severe acceleration and deceleration forces during normal operation.
- Replacement wheel rims must have the same width, diameter, offset, load capacity, and mounting configuration as the original rims to maintain vehicle safety.
- Static wheel unbalance causes wheel tramp and severe tire cupping.
- Dynamic wheel unbalance causes wheel shimmy, increased tire wear, unstable directional control, driver fatigue, and increased wear on suspension and steering components.

Review Questions

Short Answer Essays

1. State general tire functions.
2. Explain the purpose of the tire bead and bead filler.
3. Describe the purpose of antioxidants in the tire sidewall.
4. Describe the difference between a bias-ply and radial-ply tire.
5. Explain the advantages of all-season tires compared to conventional tires.
6. Describe the difference between a B and D tire load rating.
7. Explain the difference between an A and C tire temperature rating.
8. Define tire contact area and tire deflection.
9. Explain the purpose of the wheel rim drop center and safety ridges.
10. Describe the results of static unbalance.

Fill-in-the-Blanks

1. To calculate the tire aspect ratio, the tire section height is divided by the _______________.
2. All-season tires have higher average _______________ compared to non-all-season tires.
3. Studded tires cause _______________ damage.
4. Replacement tires should be installed in pairs on the same _______________.

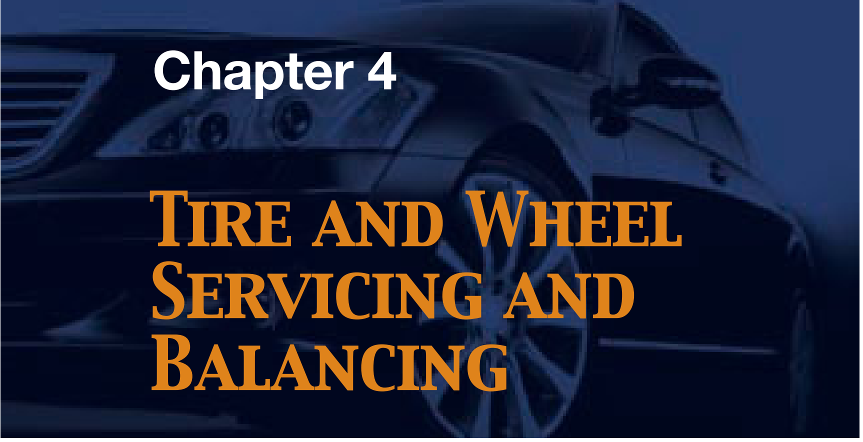
5. When a high-pressure minispare tire is installed on a vehicle, driving speed should not exceed _______________ mph.
6. The rolling diameter of a tire is _______________ than the free tire diameter.
7. When a tire deflects in the contact area, the tread grooves take up excess rubber and prevent _______________.
8. Car manufacturers recommend that tire inflation pressures should be checked when the tires are _______________.
9. When a vehicle is traveling at 55 mph, the exact top of the tire is moving at _______________ mph.
10. The rim offset is the vertical distance between the rim centerline and the _______________ of the disc.

Multiple Choice

1. In a radial-ply tire the steel or fiberglass belt cords are crisscrossed in relation to the tire centerline at an angle of:
   A. 10° to 30°. C. 20° to 35°.
   B. 15° to 35°. D. 30° to 45°.
2. In a radial-ply tire the angle of the ply cords in relation to the tire centerline is:
   A. 60°. C. 85°.
   B. 72°. D. 90°.
3. All of these statements about radial-ply tires are true EXCEPT:
   A. A belted radial-ply tire has less rolling resistance than a belted bias-ply tire.
   B. A belted radial-ply tire provides longer tire tread life than a belted bias-ply tire.
   C. A belted radial-ply tire provides improved steering characteristics compared to a bias-ply belted tire.
   D. A belted radial-ply passenger car tire can have four plies and four belts.
4. Dynamic wheel unbalance can result in:
   A. Lateral wheel shimmy.
   B. Increased steering effort.
   C. Tire and wheel tramp.
   D. Normal tire tread life.
5. When a tire has a conicity problem:
   A. The tire has excessive lateral runout.
   B. The tire has too much radial runout.
   C. The tire is cone shaped and not level across the tread area.
   D. The tire has separation between the cord plies in the sidewall.
6. When explaining tire ratings to the customer:
   A. A P speed rating indicates the tire has a 130 mph (210 km/h) capability.
   B. Tire speed ratings are based on laboratory tests.
   C. Tire traction ratings are based on five skid tests.
   D. A tire with a C traction rating has better traction than a tire with an A traction rating.
7. Nitrogen tire inflation provides:
   A. Reduced tire rolling resistance.
   B. Improved puncture resistance.
   C. More stable tire pressure.
   D. Improved ride quality.
8. All these statements about tires and wheels in motion are true EXCEPT:
   A. When a vehicle is traveling at 50 mph (80 km/h), the top of each tire is moving at 100 mph (160 km/h).
   B. Wheel rotation subjects the tires to centrifugal force.
   C. When traveling at 60 mph (96.5 km/h), the front portion of each tire is accelerating.
   D. A soft spot in a tire may cause cupped tire tread wear.

9. Static wheel unbalance causes:
   A. Cupped tire tread wear.
   B. Even wear on one edge of the tire tread.
   C. Even wear on the center of the tire tread.
   D. Feathered tire tread wear.

10. When installing replacement tires:
    A. Different tire sizes can be installed on the same axle.
    B. Snow tires can be a different type or size than the original tires on the vehicle.
    C. If the tire size is different than the original tire size, antilock brake system operation can be adversely affected.
    D. A four-wheel-drive vehicle can have different size tires on the front and rear wheels.



Chapter 4

Tire and Wheel Servicing and Balancing

Upon completion and review of this chapter, you should be able to:

- Diagnose tire thump and vibration problems.
- Diagnose steering pull problems related to tire condition.
- Rotate tires according to the vehicle manufacturer's recommended procedure.
- Remove and replace tire-and-wheel assemblies.
- Dismount, inspect, repair, and remount tires.
- Inspect wheel rims.
- Diagnose and service tire pressure monitoring systems.
- Measure tire and wheel radial and lateral runout.
- Diagnose problems caused by excessive radial or lateral tire-and-wheel runout.
- Measure tire tread wear.
- Perform off-car static wheel balance procedures.
- Perform off-car dynamic wheel balance procedures.
- Diagnose tire wear problems caused by tire and wheel imbalance.
- Perform on-car balance procedures.
- Diagnose comprehensive vibration problems.

BASIC TOOLS

Basic technician's tool set

Service manual

Tire repair kit

Tread depth gauge

Proper servicing of tires and wheels is extremely important to maintain vehicle safety and provide normal tire life. Improperly serviced and/or balanced tires and wheels cause wheel vibration and shimmy problems, resulting in excessive tire tread wear, increased wear on suspension and steering components, and decreased vehicle stability and steering control.

Tire Noises and Steering Problems

Diagnosis of Tire Noises

Tire thump may be defined as a pounding noise caused by tire and wheel rotation.

Uneven tread surfaces may cause tire noises that seem to originate elsewhere in the vehicle. These noises may be confused with differential noise. Differential noise usually varies with acceleration and deceleration, whereas tire noise remains more constant in relation to these forces. Tire noise is most pronounced on smooth asphalt road surfaces at speeds of 15 to 45 mph (24 to 72 km/h).

Tire Thump and Vibration

Tire vibration is a fast shaking of the tire that is transferred to the chassis and passenger compartment.

When tire thump and tire vibration are present, check these items:

1. Cupped tire treads
2. Excessive tire **radial runout**
3. Manufacturing defects such as heavy spots, weak spots, or tread chunking
4. Incorrect wheel balance

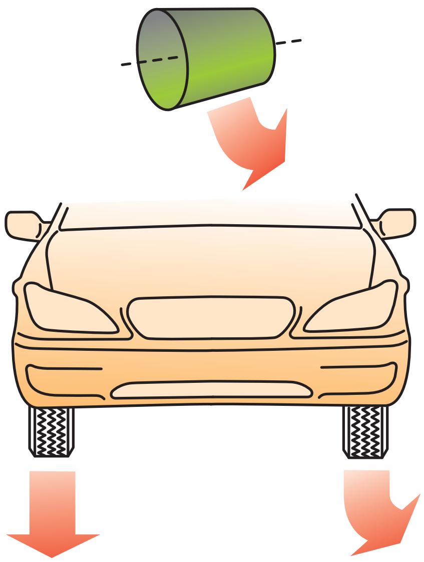


FIGURE 4-1 **Tire conicity.**

SERVICE TIP: Tire noise varies with road surface conditions, whereas differential noise is not affected when various road surfaces are encountered.

Radial runout refers to a tire out-of-round condition.

Steering Pull

A vehicle should maintain the straight-ahead forward direction on smooth, straight road surfaces without excessive steering wheel correction by the driver. If the steering gradually pulls to one side on a smooth, straight road surface, a tire, steering, or suspension defect is present. Tires of different types, sizes, designs, or inflation pressures on opposite sides of a vehicle cause **steering pull.** Sometimes a tire manufacturing defect occurs in which the belts are wound off center on the tire. This condition is referred to as **tire conicity.** A cone-shaped object rolls in the direction of its smaller diameter. Similarly, a tire with conicity tends to lead, or pull, to one side, which causes the vehicle to follow the action of the tire (Figure 4-1).

Steering pull is the tendency of the steering to gradually pull to the right or left when the vehicle is driven straight ahead on a reasonably smooth, straight road.

Because tire conicity cannot be diagnosed by a visual inspection, it must be diagnosed by switching the two front tires and reversing the front and rear tires (Figure 4-2). Incorrect front suspension alignment angles also cause steering pull.

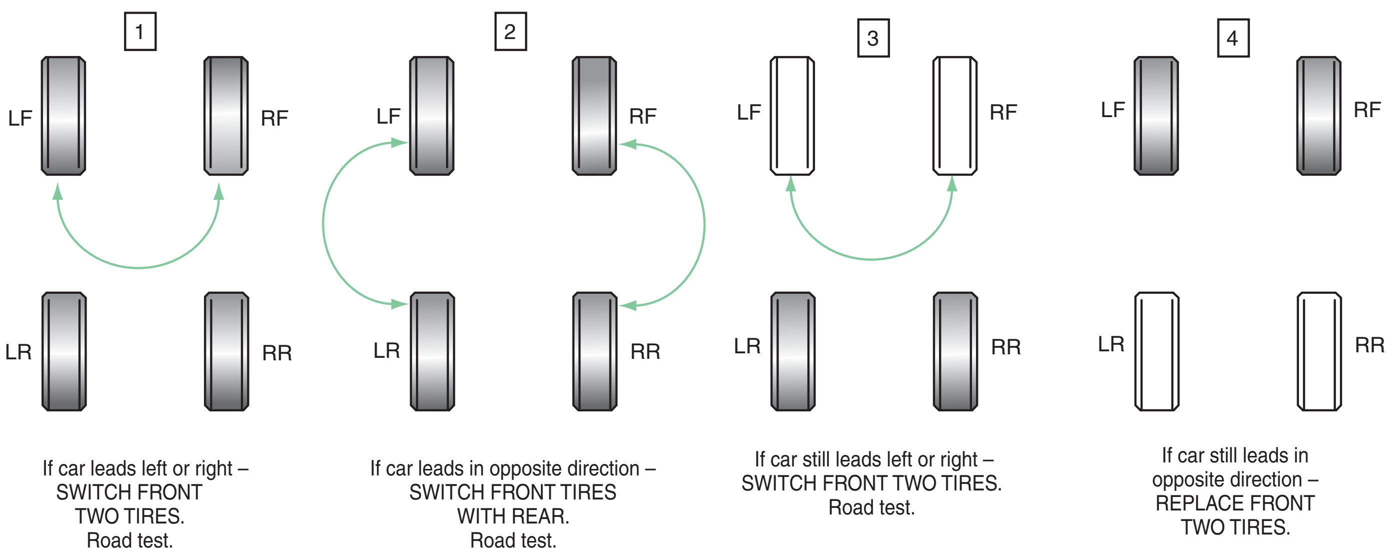


FIGURE 4-2 **Tire conicity diagnosis.**

SERVICE TIP: Tire conicity is not visible. It can be diagnosed only by changing the tire and wheel position.

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Some wheel balancers with force variation capabilities sense and indicate tire conicity defects. These wheel balancers have a roller that presses against the tire tread during the wheel balance procedure, and this roller senses tire conicity.

Tire Rotation

Driving habits determine tire life to a large extent. Severe brake applications, high-speed driving, turning at high speeds, rapid acceleration and deceleration, and striking curbs are just a few driving habits that shorten tire life. Most car manufacturers recommend **tire rotation** at specified intervals to obtain maximum tire life. The exact tire rotation procedure depends on the model year, the type of tires, and whether the vehicle has a conventional spare or a compact spare (Figure 4-3). Tire rotation procedures do not include the compact spare. The vehicle manufacturer provides tire rotation information in the owner's manual and service manual. Vehicle manufacturers usually recommend different tire rotation procedures for bias-ply tires than for radial tires (Figure 4-4).

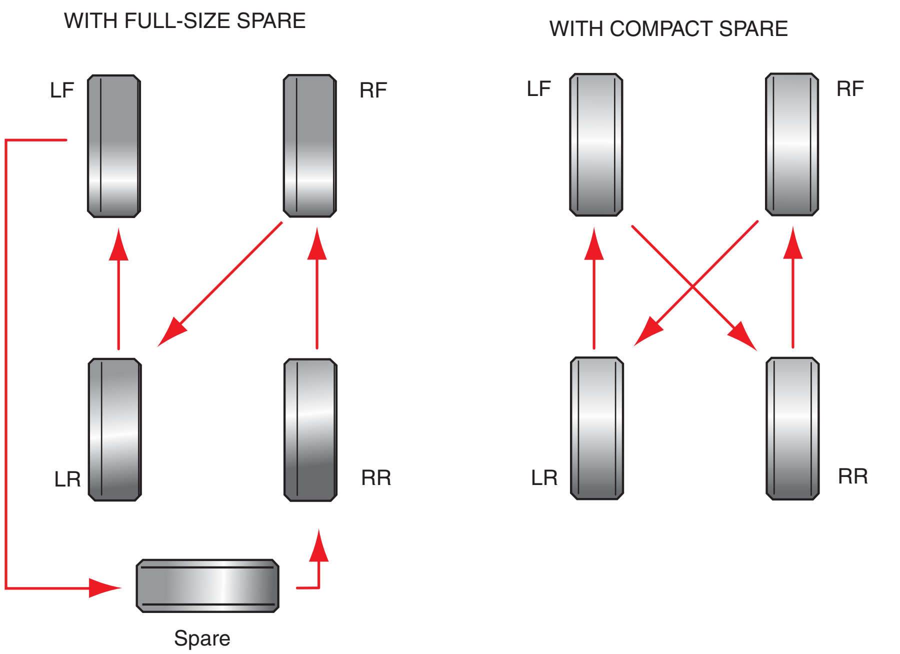

FIGURE 4-3 **Radial tire rotation procedure.**

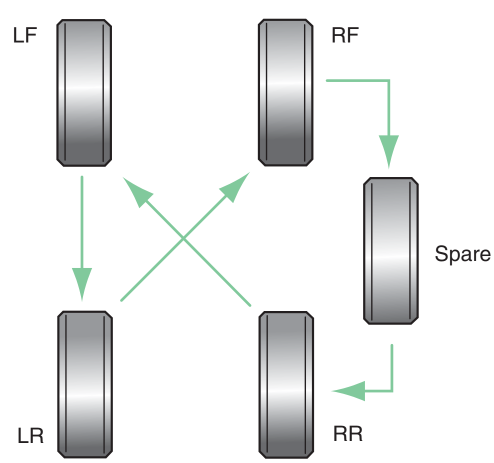

FIGURE 4-4 **Bias-ply tire rotation procedure.**

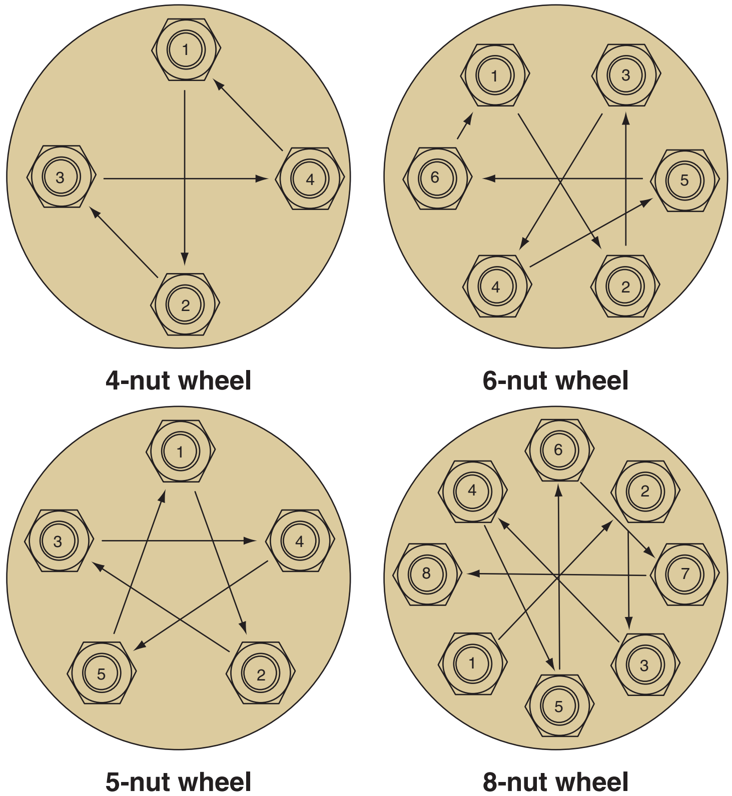

FIGURE 4-5 **Wheel nut tightening sequence.**

When tires and wheels are installed on a vehicle, it is very important that the wheel nuts are torqued to manufacturer's specifications in the proper sequence (Figure 4-5). Do not use an impact wrench when tightening wheel nuts to the specified torque.

Tire and Wheel Service

Tire and Wheel Removal

Customer Care: During many automotive service operations, including tire and wheel service, the technician literally has the customer's life in his or her hands! Always perform tire and wheel service carefully and thoroughly. Watch for unsafe tire or wheel conditions, and report these problems to the customer. When you prove to the customer that you are concerned about vehicle safety, you will probably have a steady customer.

When it is necessary to remove a tire-and-wheel assembly, follow these steps:

1. Remove the wheel cover. If the vehicle is equipped with **antitheft locking wheel covers**, the lock bolt for each wheel cover is located behind the ornament in the center of the wheel cover. A special key wrench is supplied to the owner for ornament and lock bolt removal. If the customer's key wrench has been lost, a master key is available from the vehicle dealer.
2. Loosen the wheel lug nuts about one-half turn, but do not remove the wheel nuts. Some vehicles are equipped with **antitheft wheel nuts**. A special lug nut key is supplied to the vehicle owner. This lug nut key has a hex nut on the outer end and a special internal projection that fits in the wheel nut opening. Install the lug nut key on the lug nuts, and connect the lug nut wrench on the key hex nut to loosen the lug nuts.

SERVICE TIP: On some current vehicles, such as the 2004 Cadillac SRX, the front and rear tires have dissimilar widths. For example, if one of these cars has a V8 engine, the vehicle is equipped with 18 in. wheels, and the front tire size is P235/60R18 while the rear tire size is P255/55R18. These tires must not be rotated from front to rear, but they can be rotated from side-to-side.

SERVICE TIP: Some wheel covers have fake plastic lug nuts that must be removed to access the lug nuts. Be careful not to break the fake lug nuts.

Antitheft locking wheel covers prevent unauthorized personnel from removing the wheel covers.

Antitheft wheel nuts prevent unauthorized personnel from removing the wheel nuts.

WARNING: Before the vehicle is raised on a hoist, be sure that the hoist is lifting on the car manufacturer's recommended lifting points. If the hoist is not lifting on the car manufacturer's recommended lift points, chassis components may be damaged, and the vehicle may slip off the hoist, resulting in personal injury.

CAUTION: If heat is used to loosen a rusted wheel, the wheel and/or wheel bearings may be damaged.

WARNING: If the vehicle is lifted with a floor jack, place safety stands under the suspension or frame, and lower the vehicle onto the safety stands. Then remove the floor jack from under the vehicle. If the vehicle is not supported properly on safety stands, the vehicle may suddenly drop, resulting in personal injury.

3. Raise the vehicle on a hoist or with a floor jack to a convenient working level.
4. Chalk mark the tire, wheel, and one of the lug nuts so the tire and wheel can be reinstalled in the same position.
5. Remove the lug nuts and the tire-and-wheel assembly. If the wheel is rusted and will not come off, hit the inside of the wheel with a large rubber mallet. Do not hit the wheel with a steel hammer, because this action could damage the wheel. Do not heat the wheel.

Tire and Wheel Service Precautions

There are many different types of tire changing equipment in the automotive service industry. However, specific precautions apply to the use of any tire changing equipment.

These precautions include the following:

1. Before you operate any tire changing equipment, always be absolutely certain that you are familiar with the operation of the equipment.
2. When operating tire changing equipment, always follow the equipment manufacturer's recommended procedure.
3. Always deflate a tire completely before attempting to dismount the tire.
4. Clean the bead seats on the wheel rim before mounting the tire on the wheel rim.
5. Lubricate the outer surface of the tire beads with rubber lubricant before mounting the tire on the wheel rim.
6. When the tire is mounted on the wheel rim, be sure the tire is positioned evenly on the wheel rim.
7. While inflating a tire, do not stand directly over the tire. An air hose extension allows the technician to stand back from the tire during the inflation process.
8. Do not overinflate tires.
9. When mounting tires on cast aluminum alloy wheel rims or cast magnesium alloy wheel rims, always use the tire changing equipment manufacturer's recommended tools and procedures.
10. When mounting or dismounting run-flat tires, be sure the tire changing equipment is compatible with these tires and wheels.

CAUTION: Never use petroleum-based lubricants on tire beads. This action damages the beads.

CAUTION: If hand tools or tire irons are used to dismount tires, tire bead and wheel rim damage may occur.

Tire Dismounting

Always use a tire changer to dismount tires. Do not use hand tools or tire irons for this purpose. Various types of tire changers are available. When servicing tires it is very important that the tire changing equipment will mount and dismount run-flat tires, low-profile tires, and tires mounted on alloy wheels without damaging the wheel rims or tires. Some

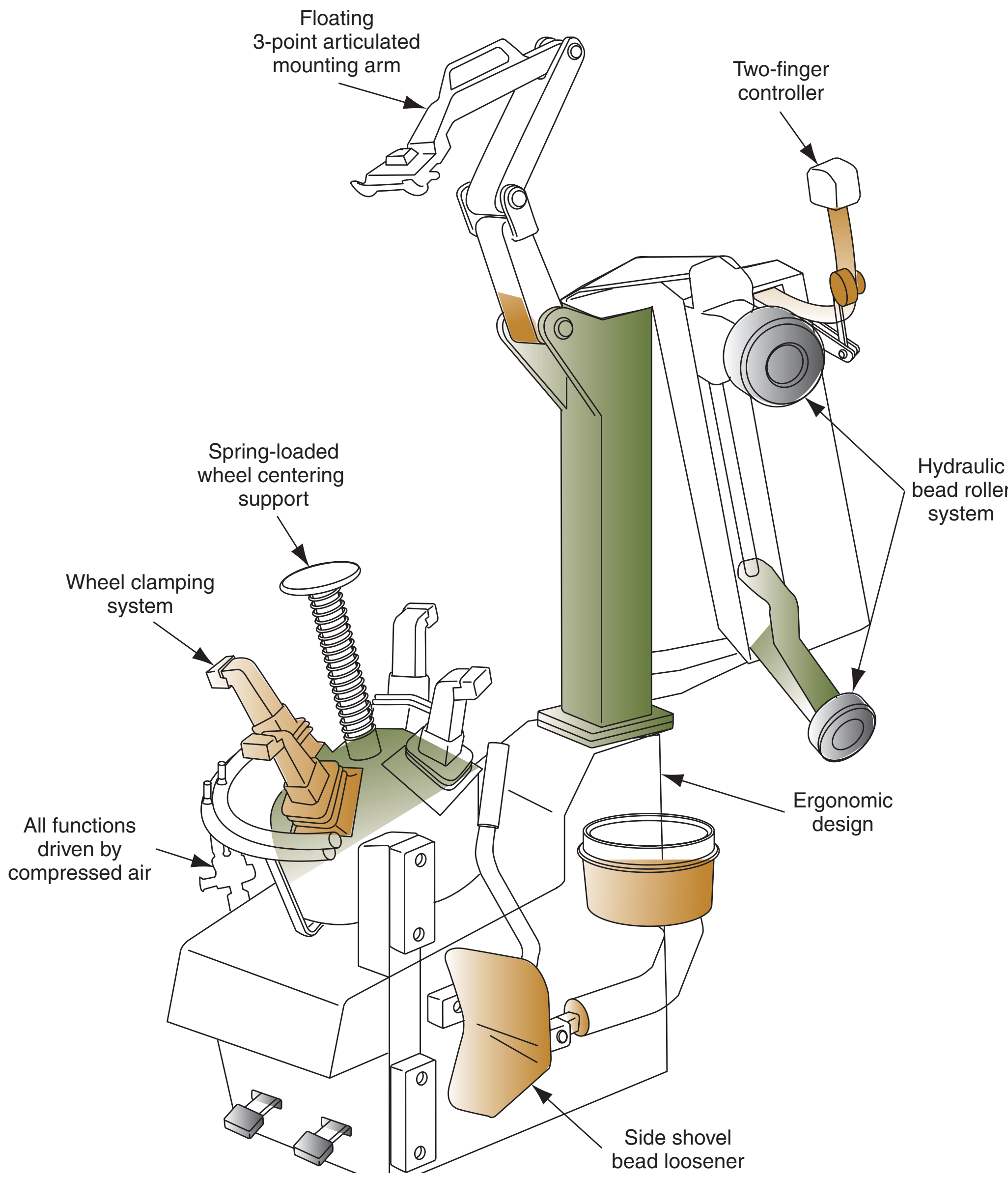

FIGURE 4-6 **Tire changer.**

tire changers have the features illustrated in Figure 4-6 and described in the following explanation:

1. A floating 3-point articulated arm has a polymer mount/dismount head on the end of the arm. This type of mount/dismount head goes between the tire bead and the rim when dismounting or mounting the tire (Figure 4-7). The polymer head will not damage alloy wheel rims. A mechanical bead pusher with a nylon roller facilitates handling stiff, low-profile tires.
2. A spring-loaded wheel centering support centers the wheel rim in the clamping system.
3. A rubber-pad clamping system eliminates steel-jaw clamping and wheel rim damage. The rim clamping system easily adjusts for internal or external rim clamping (Figure 4-8).
4. A multi-piston air motor in the tire changer drives the clamp assembly and wheel rim in either direction up to 15 revolutions per minute (rpm). The technician controls the clamp and wheel rim rotation by foot-operated pedals on the front of the tire changer. This type of clamping system allows the technician to rotate the wheel rim inside the tire to correct excessive wheel and tire runout conditions.

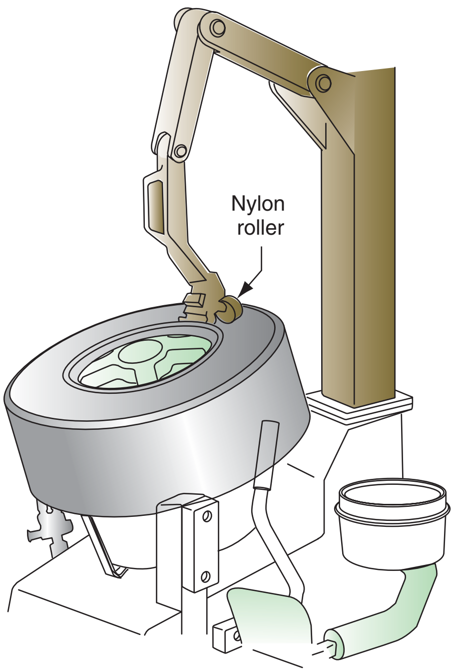

FIGURE 4-7 **Articulating arm with polymer head and mechanical bead pusher.**

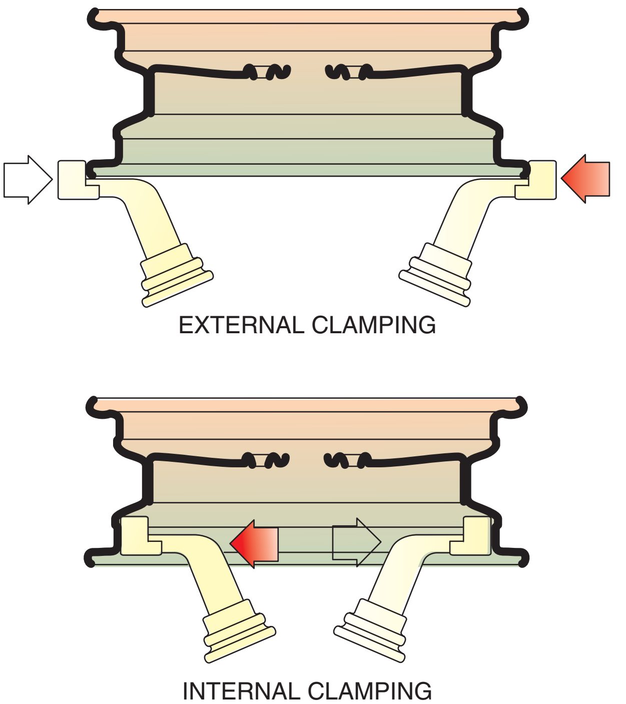

FIGURE 4-8 **Rim clamping system provides internal or external rim clamping action.**

5. The technician uses two fingers to operate control switches that control the upper and lower bead rollers by air-over-hydraulic pressure.
6. The nonmetal bead rollers are placed against the tire next to the rim, and the technician uses the control switches to supply pressure to the rollers (Figure 4-9). The clamp and wheel assembly is rotated to loosen the upper and lower beads.
7. The tire changer is designed so the complete bead loosening, tire dismounting, and tire mounting operation can be performed from one position, which saves time and physical energy.

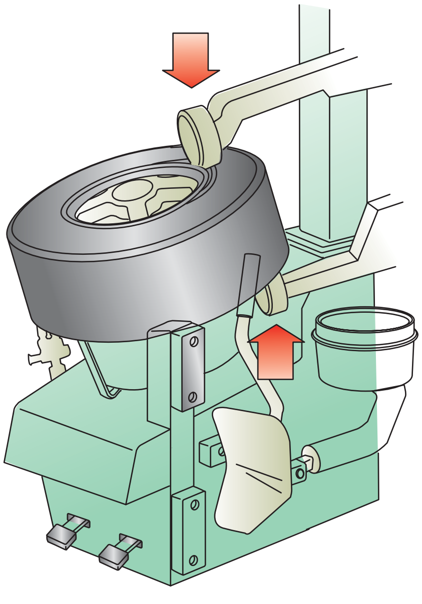

FIGURE 4-9 **Bead loosening rollers.**

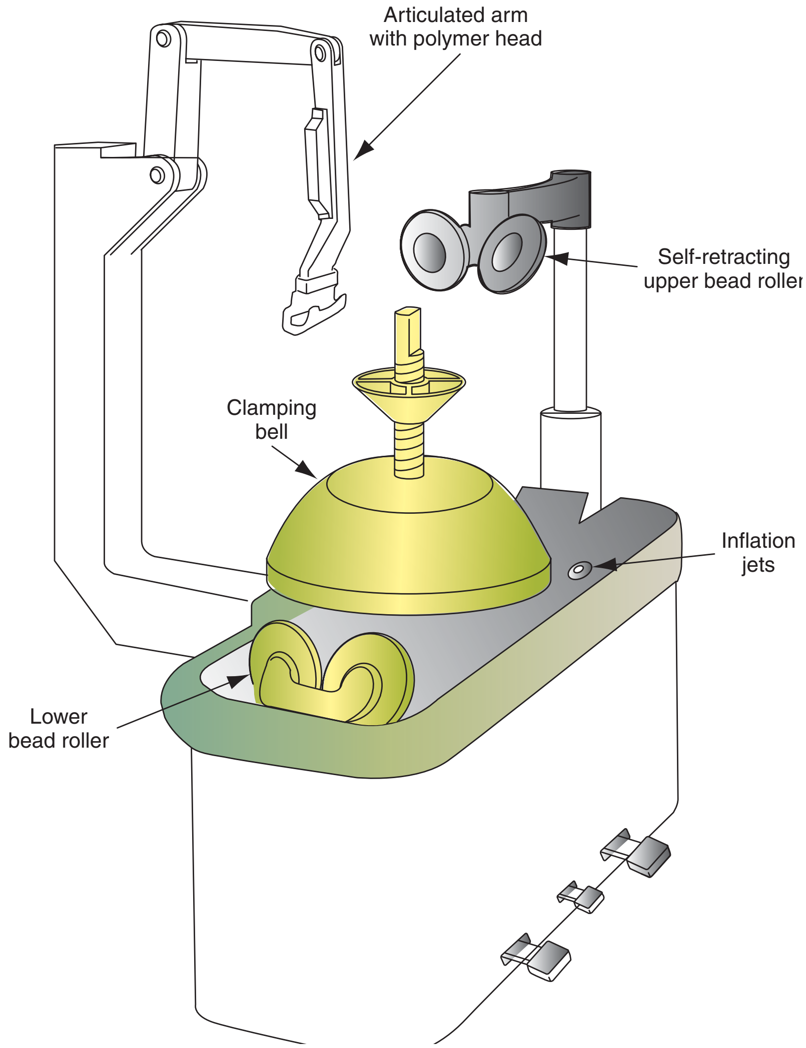

FIGURE 4-10 **Tire changer with horizontal clamping mechanism.**

8. A side shovel bead-loosening tool is an optional feature that facilitates dismounting and mounting tires on special applications such as motorcycles and all-terrain vehicles (ATVs).

Other tire changers have similar features but a different tire and wheel assembly mounting (Figure 4-10). The tire and wheel assembly is mounted on a clamping bell that centers the wheel on the bell. A threaded center post is mounted in the center of the clamping bell. After the tire and wheel assembly is placed on the clamping bell, a tapered cone is threaded onto the center post to retain the tire and wheel assembly. The nonmetal bead rollers are used to loosen the upper and lower beads. On alloy wheels the polymer head on the articulating arm is used to dismount and mount the tire. On steel wheels a steel mount tool may be placed through the center post and under the tire bead, and the tire and wheel assembly is rotated to dismount or mount the tire (Figure 4-11). Many tire changers have inflation jets in the clamping mechanism to supply air pressure to the inside of the tire and inflate the tire after the tire is mounted properly.

A typical tire dismounting procedure follows:

1. Remove the valve core and be sure the tire is completely deflated.
2. Place the wheel and tire on the tire changer with the narrow bead ledge facing upward.

SPECIAL TOOLS
Tire changer

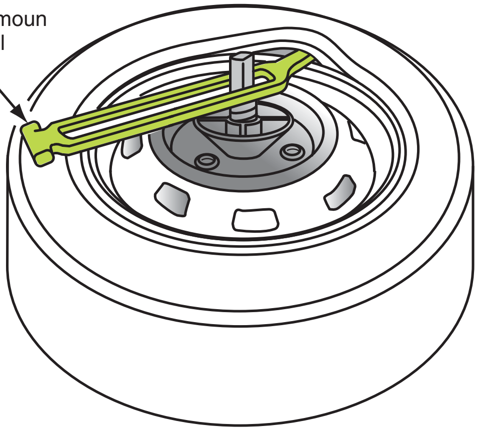

FIGURE 4-11 **Steel mount/demount tool for steel rims.**

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3. Follow the operating procedure recommended by the manufacturer of the tire changer to force the tire bead inward and separate it from the rim on both sides.
4. Push one edge of the top bead into the drop center of the rim.
5. Place the tire changer's head or lever between the bead and the rim on the opposite side of the rim from where the bead is in the drop center.
6. Operate the tire changer to rotate the head or lever and move the bead over the top of the rim.
7. Repeat steps 4, 5, and 6 to move the lower bead over the top of the rim.

CAUTION:
The use of sealants or cord plugs when repairing PAX tires will immediately void the tire warranty.

PAX Tire Service

PAX tires are usually serviced at Michelin-authorized PAX tire dealers. Some car dealerships that sell cars with original equipment PAX tires may be authorized Michelin PAX dealers. Other car dealerships will only provide complete PAX tire and wheel replacements. If PAX tires are punctured in the tread area, they are repairable.

Special tire changing equipment is required to dismount and mount PAX tires. An accessory kit and a different press arm may be installed on some tire changers to upgrade the changer to PAX capabilities. A PAX accessory kit and PAX press arm are available for the Coats 9024E tire changer (Figure 4-12). This accessory kit (Figure 4-13) contains the following items:

1. Quick release hub nut
2. Centering cones
3. Removable center shaft
4. Cushioned PAX riser
5. Dual roller tool
6. Tool holders
7. PAX bead lift tool
8. Bead flip tool
9. Plain bead lock tool
10. Spring-loaded bead lock tool
11. Plastic protectors
12. Tapered roller

CAUTION:
If a tire changer without PAX capabilities is used to attempt PAX tire dismounting and mounting, tire and wheel damage may occur.

When dismounting and mounting PAX tires, follow the procedure specified by the tire changer manufacturer. All PAX tires have a tire pressure monitoring system (TPMS). Service precautions related to TPMS systems must be observed when servicing PAX tires and wheels.

FIGURE 4-12 **Tire changer adaptable to PAX here.**

FIGURE 4-13 **Tire changer accessory kit for PAX tire services.**

When a PAX tire is dismounted, always inspect the deflation ring mounted on the wheel. If the ring is damaged, it must be replaced.

Tire Inspection and Repair

To find a leak in a tire and wheel, inflate the tire to the pressure marked on the sidewall, and then submerge the tire and wheel in a tank of water. An alternate method of leak detection is to sponge soapy water on the tire and wheel. Bubbles will appear wherever the leak is located in the tire or wheel. Mark the leak location in the tire or wheel rim with a crayon, and mark the tire at the valve stem location so the tire can be reinstalled in the same position on the wheel to maintain proper balance.

A puncture is the most common cause of a tire leak, and many punctures can be repaired satisfactorily. Do not attempt to repair punctures over 1/4 in. in diameter. Punctures in the sidewalls or on the tire shoulders should not be repaired. The repairable area in belted bias-ply tires is approximately the width of the belts (Figure 4-14). The belts in radial tires are wider than those in bias-ply tires. The repairable area in radial tires is also the width of the belts. Because compact spare tires have thin treads, do not attempt to repair these tires.

Inspect the tire; do not repair a tire with any of the following defects, signs of damage, or excessive wear:

1. Tires with the wear indicators showing
2. Tires worn until the fabric or belts are exposed
3. Bulges or blisters
4. **Ply separation**
5. Broken or cracked beads
6. Cuts or cracks anywhere in the tire

Because most vehicles are equipped with tubeless tires, we will discuss this type of tire repair. If the cause of the puncture, such as a nail, is still in the tire, remove it from the tire.

When **ply separation** occurs, the tire plys are pulled apart. This condition often appears as a bulge on the tire surface.

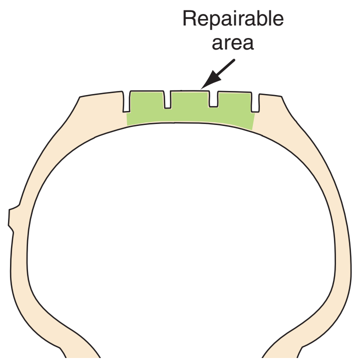

FIGURE 4-14 **Repairable area on bias-ply and belted bias-ply tires.**

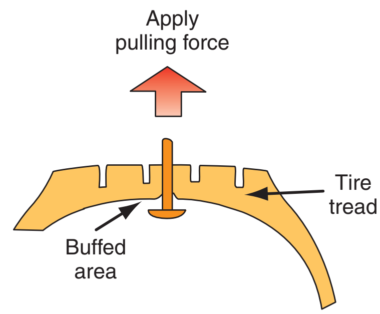

FIGURE 4-15 **Plug installation procedure.**

CAUTION:
Radial tire patches should have arrows that must be positioned parallel to the radial plies to provide proper adhesion.

Most punctures can be repaired from inside the tire with a service plug or vulcanized patch service kit. The instructions of the tire service kit manufacturer should be followed, but we will discuss three common tire repair procedures.

Plug Installation Procedure

1. Buff the area around the puncture with a wire brush or wire buffing wheel.
2. Select a plug slightly larger than the puncture opening, and insert the plug in the eye of the insertion tool.
3. Wet the plug and the insertion tool with vulcanizing fluid.
4. While holding and stretching the plug, pull the plug into the puncture from the inside of the tire (Figure 4-15). The head of the plug should contact the inside of the tire. If the plug pulls through the tire, repeat the procedure.
5. Cut the plug off 1/32 in. from the tread surface. Do not stretch the plug while cutting.

CAUTION:
The use of abrasive cleaners, alkaline-base detergents, or caustic agents on aluminum or magnesium wheel rims may cause discoloration or damage to the protective coating.

Cold Patch Installation Procedure

1. Buff the area around the puncture with a wire brush or buffing wheel.
2. Apply vulcanizing fluid to the buffed area and allow it to dry until it is tacky.
3. Peel the backing from the patch, and apply the patch over the puncture. Center the patch over the puncture.
4. Run a stitching tool back and forth over the patch to improve bonding.

Hot Patch Installation Procedure

1. Buff the area around the puncture with a wire brush or buffing wheel.
2. Apply vulcanizing fluid to the buffed area, if required.
3. Peel the backing from the patch and install the patch so it is centered over the puncture on the inside of the tire. Many hot patches are heated with an electric heating element clamped over the patch. This element should be clamped in place for the amount of time recommended by the equipment or patch manufacturer.
4. After the heating element is removed, allow the patch to cool for a few minutes and be sure the patch is properly bonded to the tire.

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Wheel Rim Service

Steel rims should be spray cleaned with a water hose. Aluminum or magnesium wheel rims should be cleaned with a mild soap and water solution, and rinsed with clean water. The use of abrasive cleaners, alkaline-base detergents, or caustic agents may damage aluminum or

magnesium wheel rims. Clean the rim bead seats on these wheel rims thoroughly with the mild soap and water solution. The rim bead seats on steel wheel rims should be cleaned with a wire brush or coarse steel wool.

Steel wheel rims should be inspected for excessive rust and corrosion, cracks, loose rivets or welds, bent or damaged bead seats, and elongated lug nut holes. Aluminum or magnesium wheel rims should be inspected for damaged bead seats, elongated lug nut holes, cracks, and porosity. If any of these conditions are present on either type of wheel rim, replace the wheel rim.

Many shops always replace the tire valve assembly when a tire is repaired or replaced. This policy helps prevent future problems with tire valve leaks. The inner end of the valve may be cut off with a pair of diagonal pliers, and then the outer end may be pulled from the rim. Coat the new valve with rubber tire lubricant and pull it into the rim opening with a special puller screwed onto the valve threads.

CAUTION: Steel wheel rims must not be welded, heated, or peened with a ball-peen hammer. These procedures may weaken the rim and create a safety hazard.

Wheel Rim Leak Repair

A wheel rim leak may be repaired if the leak is not caused by excessive rust on a steel rim, and the rim is in satisfactory condition.

Follow these steps for wheel rim leak repair:

1. Use #80-grit sandpaper to thoroughly clean the area around the leak on the tire side of the rim.
2. Use a shop towel to remove any grit from the leak area.
3. Be sure the wheel rim is at room temperature, and apply a heavy coating of silicone rubber sealer over the leak area.
4. Spread the sealer over the entire sanded area with a putty knife.
5. Allow the sealer to cure for six hours before remounting the tire.

CAUTION: Installing an inner tube to correct leaks in a tubeless tire or wheel rim is not an approved procedure.

Tire Remounting Procedure

1. Be sure the wheel rim bead seats are thoroughly cleaned.
2. Coat the tire beads and the wheel rim bead seats with rubber tire lubricant.
3. Secure the wheel rim on the tire changer with the narrow bead ledge facing upward, and place the tire on top of the wheel rim with the bead on the lower side of the tire in the drop center of the wheel rim.
4. Use the tire changer head or lever under the tire bead to install the tire bead over the wheel rim. Always operate the tire changer with the manufacturer's recommended procedure.
5. Repeat steps 3 and 4 to install the upper bead over the wheel rim.
6. Rotate the tire on the wheel rim until the crayon mark is aligned with the valve stem. This mark was placed on the tire prior to dismounting.

WARNING: When a bead expander is installed around the tire, never exceed 10 psi (69 kPa) pressure in the tire. A higher pressure may cause the expander to break and fly off the tire, causing serious personal injury or property damage.

WARNING: When a bead expander is not used, never exceed 40 psi (276 kPa) tire pressure to move the tire beads out tightly against the wheel rim. A higher pressure may blow the tire bead against the rim with excessive force, and this action could burst the rim or tire, resulting in serious personal injury or property damage.

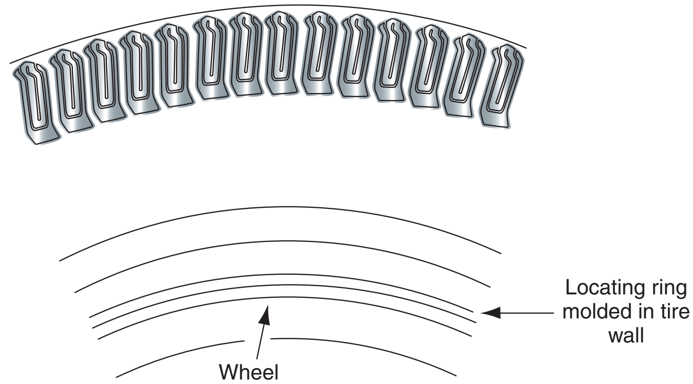

FIGURE 4-16 **The circular ring around the tire bead must be centered on the wheel rim.**

WARNING: While inflating a tire, do not stand directly over the tire. In this position, serious injury could occur if the tire or wheel rim flies apart.

7. Follow the recommended procedure supplied by the manufacturer of the tire changer to inflate the tire. This procedure may involve the use of a bead expander installed around the center of the tire tread to expand the tire beads against the wheel rim. If a bead expander is used, inflate the tire to 10 psi (69 kPa) to move the beads out tightly against the wheel rim. Never exceed this pressure with a bead expander installed on the tire. Always observe the circular marking around the tire bead as the tire is inflated. This mark should be centered around the wheel rim (Figure 4-16). Always observe both beads while a tire is inflated. If the circular mark around the tire bead is not centered on the rim, deflate the tire and center it on the wheel rim. If a bead expander is not used, never exceed 40 psi (276 kPa) when moving tire beads out tightly against the rim. When either tire bead will not move out tightly against the wheel rim with 40 psi (276 kPa) tire pressure, deflate the tire and center it on the wheel rim again.

Photo Sequence 5 shows a typical procedure for dismounting and mounting a tire on a wheel assembly.

Diagnosing and Servicing Tire Pressure Monitoring Systems

Visual Inspection

If the tire pressure monitoring system (TPMS) warning light is illuminated and/or a warning message is displayed in the message center, the first step in diagnosing the system is a visual inspection. During this inspection be sure each tire is inflated to the specified pressure. Make sure all fours or five tires are the size specified by the vehicle manufacturer, and that each wheel contains a tire pressure sensor. Inspect the wiring harness connection to the TPMS module for loose or corroded connections and damaged wires.

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Scan Tool Diagnosis

The vehicle manufacturer's recommended diagnostic procedure varies considerably depending on the vehicle model year. Most systems are diagnosed using a scan tool with TPMS capabilities. The following is a typical scan tool diagnosis. If the visual inspection does not reveal any defects, use a scan tool to proceed with the diagnostic system check.

Typical Procedure for Dismounting and Mounting a Tire on a Wheel Assembly

P5-1 **Dismounting the tire from the wheel begins with releasing the air, removing the valve stem core, and unseating the tire from its rim. The machine does the unseating. The technician merely guides the operating lever.**

P5-2 **Once both sides of the tire are unseated, place the tire and wheel onto the machine. Then depress the pedal that clamps the wheel to the tire machine.**

P5-3 **Lower the machine's arm, into position on the tire-and-wheel assembly.**

P5-4 **Insert the tire iron between the upper bead of the tire and the wheel. Depress the pedal that causes the wheel to rotate. Do the same with the lower bead.**

P5-5 **After the tire is totally free from the rim, remove the tire.**

P5-6 **Prepare the wheel for the mounting of the tire by using a wire brush to remove all dirt and rust from the sealing surface. Apply rubber compound to the bead area of the tire.**

P5-7 **Place the tire onto the wheel and lower the arm into place. As the machine rotates the wheel, the arm will force the tire over the rim. After the tire is completely over the rim, install the air ring over the tire. Activate it to seat the tire against the wheel.**

P5-8 **Reinstall the valve stem core and inflate the tire to the recommended inflation.**

Diagnostic System Check

The diagnostic system check provides the following information:

1. Identification of the control modules in the TPMS system.
2. Indication of the ability of the system control modules to communicate through the serial data circuit.
3. Indication of any diagnostic trouble codes (DTCs) stored in the system control modules.

Follow these steps to complete the diagnostic system check.

1. Connect a scan tool to the data link connector (DLC) under the left side of the instrument panel, and turn the scan tool on.
2. Turn the ignition switch on, and do not start the engine.
3. Select antenna module on the scan tool. Check for the DTCs related to the antenna module. If there are DTCs displayed with a "U" prefix, there is a defect in the data link communications. If the scan tool cannot communicate with the antenna module, or there are DTCs related to this module or the data link communications, proceed with further diagnosis of these items.
4. Check for DTCs related to the radio/audio system. The antenna grid in the rear window receives TPMS system sensor signals. This grid shares its connector with the AM/FM antenna grid. If any radio/audio system DTCs are present, proceed with the diagnosis of the radio/audio system.
5. Check for keyless entry system DTCs displayed in the scan tool. The antenna module also controls the keyless entry system. If the scan tool displays DTCs related to the keyless entry system, proceed with the diagnosis of these DTCs.
6. Check for TPMS system DTCS on the scan tool display. If TPMS system DTCs are present, diagnose the cause of these DTCs.

TPMS System Data Display

TPMS data display may be selected on the scan tool display. The data display is very useful when diagnosing the TPMS system and sensors. The following data displays may be selected on the scan tool:

1. Battery voltage—The scan tool displays the amount of battery voltage supplied to the antennal module.
2. LF pressure sensor ID—The scan tool displays an eight-digit number or an asterisk. The eight-digit number is a unique LF sensor identification number, and this display indicates the number has been learned by the antenna module. If an asterisk is displayed, the sensor ID number has not been learned by the antenna module.
3. LF pressure sensor mode—This mode display may indicate **stationary, wake, drive, re-measure, learn, low bat**, or **N/A** (not available). If **stationary** is displayed, the sensor roll switch is open and the sensor has sent a stationary message that only occurs every 60 minutes from the previous stationary transmission. A **wake** display indicates the sensor has detected an initial roll switch closure, and the sensor is changing from the stationary mode to the drive mode. A **drive** display indicates the vehicle speed is above 20 mph (32 km/h), and the sensor roll switch has been closed for a minimum of 10 seconds. In this mode the sensor transmits every 60 seconds. If **re-measure** is displayed, the sensor has detected a 1.6 psi (11 kPa) pressure change. A **learn** display indicates the sensor has been activated by a low-frequency voltage signal that occurs during a sensor re-learn procedure. A **low battery** display indicates the internal sensor battery has low voltage and sensor replacement is necessary.
4. LF tire pressure—The scan tool displays the actual tire pressure between 0 and 51 psi (0 to 344 kPa).

5. LF tire pressure sensor status—In this mode the scan tool displays **valid** or **invalid**. A **valid** display indicates the specified LF tire pressure is present. If **invalid** is displayed, the LF tire pressure is not within specifications and DTC C0750 is currently set in the antenna module memory. This DTC indicates a defective LF sensor or faulty LF sensor circuit.

The same data from each wheel sensor may be displayed on the scan tool. Other DTCs include C0755 indicating a defective LR sensor, C0760 representing a faulty RF sensor, and C0765 indicating a defect in the RR sensor. A current DTC indicates the fault causing the DTC is present at the time of diagnosis. The DTCs vary depending on the vehicle make and model year. A history DTC represents a fault that occurred in the past, but it is not present at the time of diagnosis. The vehicle speed must be above 20 mph (32 km/h) for the antenna module to run the DTC check. A DTC is set in the antenna module memory if any wheel sensor does not enter the drive mode or does not transmit any data for 10 minutes or more. When a DTC is set in the antenna module memory, the following actions are taken:

1. A DTC is stored in memory.
2. The driver information center (DIC) displays a SERVICE TIRE MONITOR message.
3. The DIC indicates row of dashes in place of the suspect tire pressure display.

A current DTC is cleared from memory when the fault causing the DTC is corrected. A history DTC is cleared after 100 consecutive fault-free ignition cycles. A scan tool may be used to clear DTCs.

Senser Replacement

Vehicles with a TPMS may require a tire pressure adjustment in relation to atmospheric temperature. For example, if the atmospheric temperature decreases 30°F when a vehicle is parked outside overnight, the tire pressure decreases 3 psi. This pressure decrease may activate the TPMS warning system. Refer to the vehicle manufacturer's specifications for tire inflation pressure at various atmospheric temperatures.

Proper valve stem and sensor removal procedures must be followed to avoid damage to the sensor: To remove a valve stem and sensor, follow these steps:

1. Before removing the tire and wheel assembly from the vehicle, mark the wheel rim in relation to one of the wheel studs.
2. Position the tire and wheel assembly with the valve stem at the 6 o'clock position.
3. Remove the sensor retention nut and push the valve stem and sensor into the tire.
4. Place the wheel and tire on the turntable of the tire changer so the valve stem is positioned 270° from the mounting/demounting arm on the tire changer (Figure 4-17).
5. Loosen both tire beads away from the wheel rim.
6. Place index marks on the tire beside the valve stem opening and the wheel weight positions.
7. Lubricate the outer tire bead, and dismount the outer bead over the wheel rim.
8. Lift up on the outer tire bead, and remove the TPMS sensor and valve stem assembly.
9. Install the new sensor in the valve stem opening, and install a new grommet and retention nut.
10. Tighten the retention nut to 71 in-lbs (8 Nm).
11. Lubricate and mount the outer tire bead.
12. Inflate the tire to the specified pressure.
13. Remove the tire and wheel from the tire changer and install this assembly in the proper position on the wheel studs. Tighten the wheel retaining nuts in the proper sequence to the specified torque.

CAUTION:
Do not remove the valve stem core to relieve the tire pressure. If the valve stem core is inadvertently removed from the valve stem, a new nickel-plated valve core must be installed. Failure to use a nickel-plated valve core will result in corrosion and possible loss of tire pressure.

CAUTION:
The tire pressure sensors are not serviceable. If a sensor is defective, it must be replaced.

CAUTION:
Tire pressure sealing products may render the TPMS sensor inoperative. If this occurs, remove all of the tire sealing material and replace the sensor.

CAUTION:
Each time a TPMS sensor is removed, a new grommet, retention nut, and valve cap must be installed. Replace the valve core if it has been removed or damaged.

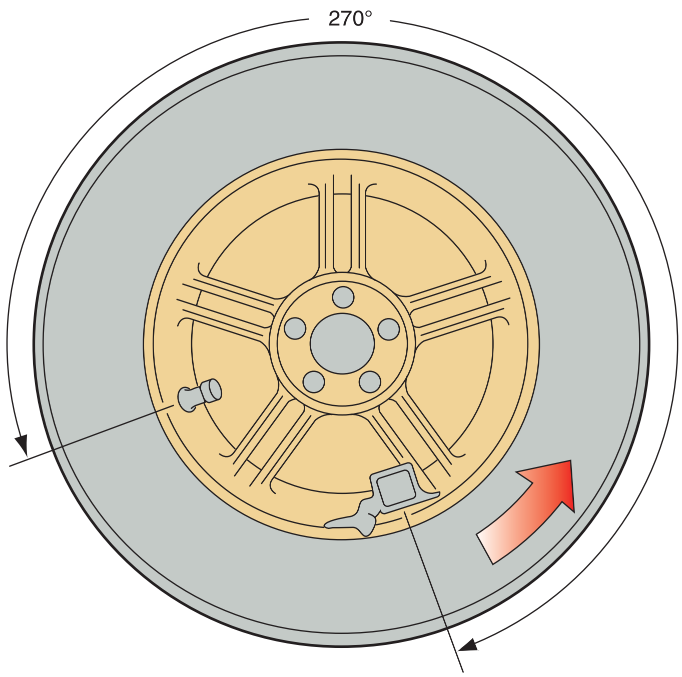

FIGURE 4-17 **Proper tire and wheel position on a tire changer.**

Sensor Learning Procedure with Magnetic Tool

If a TPMS sensor or component is serviced, a sensor learning procedure must be performed. There are a number of different sensor learning procedures depending on the vehicle make and model year. The sensor learning procedure usually involves the use of a magnetic tool or a scan tool.

Follow these steps to complete the sensor learning procedure with a magnetic tool:

SPECIAL TOOLS
Magnetic learn tool

1. Starting with the ignition switch off, cycle the ignition switch on and off three times, and on the third cycle leave the ignition switch in the on position. Do not wait more than two seconds between switch cycles.
2. Press and release the brake pedal.
3. Repeat the ignition switch cycling procedure as explained in step 1. Upon completion of this procedure, the horn should sound once to indicate successful entry to the learn mode.
4. After the horn sounds, a TRAIN LEFT FRONT TIRE message should appear in the instrument panel message center.
5. Place the special magnetic tool on the valve stem of the left front tire (Figure 4-18). When the TPMS module recognizes the left front sensor, the horn sounds momentarily.

WARNING: The special magnetic tool may adversely affect magnetically sensitive devices such as heart pacers, and this action may result in personal injury!

6. Repeat step 5 at the right front, right rear, left rear, and spare wheels.
7. If the learn procedure fails on any wheel, the horn sounds twice, and a TIRES NOT LEARNED-REPEAT message appears in the message center. If this action occurs, the learn procedure must be repeated from step 1.

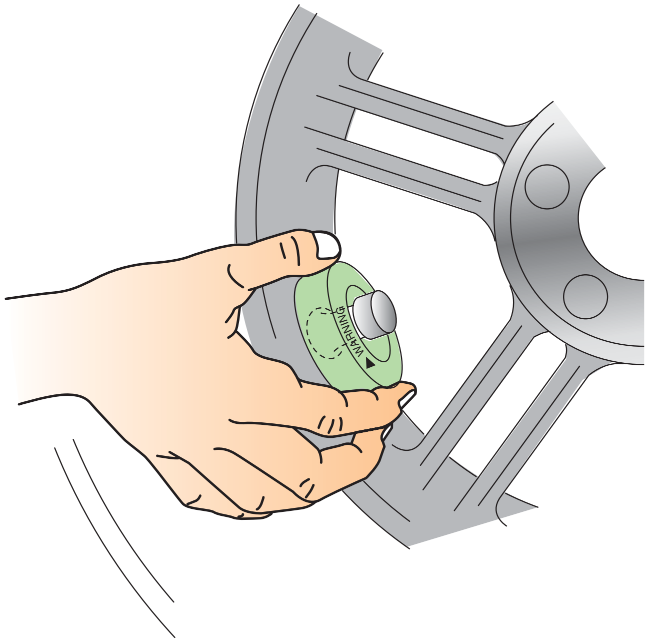

FIGURE 4-18 **Magnetic learning tool for TPMS sensors.**

Sensor Learning Procedure with Scan Tool

Follow these steps to complete the sensor learning procedure with a scan tool:

1. Connect a scan tool to the DLC.
2. Turn on the ignition switch, and do not start the engine.
3. Apply the parking brake.
4. Select Special Functions on the scan tool.
5. Select Sensor Learn Mode on the scan tool, and press the Enter key.
6. Press the On soft key. A horn chirp should sound to indicate the sensor learn mode is enabled.
7. Starting with the LF tire, increase or decrease the tire pressure for 5–8 seconds or until a horn chirp sounds. The horn chirp may occur before the 5- to 8-second time period, or up to 30 seconds after this time period.

WARNING: If you are increasing tire pressure during the learning procedure, never inflate a tire above the vehicle manufacturer's maximum specified tire pressure. This action may cause personal injury and tire damage.

8. After the horn chirp sounds, repeat step 7 on the other 3 or 4 sensors in the following order:
   (a) RF
   (b) RR
   (c) LR
   (d) Spare tire (if applicable)

If a horn chirp is not heard after 35 seconds for any of the 4 sensors, turn off the ignition switch and exit the learn mode on the scan tool. Repeat the sensor learning procedure from step 4.

9. After the learning procedure has been completed on all the sensors, a double horn chirp sounds to indicate the learning procedure is completed on all the sensors.
10. Turn off the ignition switch and disconnect the scan tool.
11. Inflate all the tires to the specified pressure.

Sensor Learning Procedure with Keyless Entry Transmitter

On some vehicles, the keyless entry remote transmitter may be used to complete the wheel sensor learning procedure without the use of any other equipment. Follow these steps to perform a sensor learning procedure using the keyless entry remote transmitter:

1. Turn on the ignition switch.
2. Apply the parking brake.
3. Use the keyless entry remote transmitter to lock and unlock the doors three times.
4. Simultaneously press the lock and unlock buttons on the keyless entry remote transmitter until a horn chirp sounds.
5. Starting with the LF tire, increase or decrease the tire pressure for 5–8 seconds, or until a horn chirp sounds. The horn chirp may sound before the 5–8 seconds is completed, or up to 35 seconds after this time period.
6. After the horn chirp sounds on the LF tire, follow the procedure in step 5 on the other 3 or 4 sensors in the following order:
   (a) RF
   (b) RR
   (c) LR
   (d) Spare (if applicable)

If a horn chirp does not sound after 35 seconds on any of the tires, turn off the ignition switch and exit the learn mode on the scan tool. Repeat the procedure starting with step 1.

7. After all the sensors have been learned, a double horn chirp sounds to indicate all the sensors have been learned.
8. Turn off the ignition switch and disconnect the scan tool.
9. Inflate all the tires to the specified tire pressure.

Tire and Wheel Runout Measurement

Ideally, a tire-and-wheel assembly should be perfectly round. However, this condition is rarely achieved. A tire-and-wheel assembly that is out-of-round is said to have radial runout. If the radial runout exceeds manufacturer's specifications, a vibration may occur because the radial runout causes the spindle to move up and down (Figure 4-19). A defective tire with a variation in stiffness may also cause this up-and-down spindle action.

Radial tire runout refers to excessive variations in the tread circumference.

Wheel balancers with force variation capabilities have a roller that is pressed against the tire tread during the wheel balance procedure. This roller senses and indicates stiffness variation in a tire.

A dial indicator gauge may be positioned against the center of the tire tread as the tire is rotated slowly to measure radial runout (Figure 4-20). Radial runout of more than 0.060 in. (1.5 mm) will cause vehicle shake. If the radial runout is between 0.045 in. to 0.060 in. (1.1 mm to 1.5 mm), vehicle shake may occur. These are typical radial runout specifications. Always consult the vehicle manufacturer's specifications. Mark the highest point of radial runout on the tire with chalk, and mark the valve stem position on the tire.

SPECIAL TOOLS
Tire runout gauge

If the radial tire runout is excessive, dismount the tire and check the runout of the wheel rim with a dial indicator positioned against the lip of the rim while the rim is rotated (Figure 4-21). Use chalk to mark the highest point of radial runout on the wheel rim. Radial wheel runout should not exceed 0.035 in. (0.9 mm), whereas the maximum lateral wheel runout is 0.045 in. (1.1 mm). If the highest point of wheel radial runout coincides with the

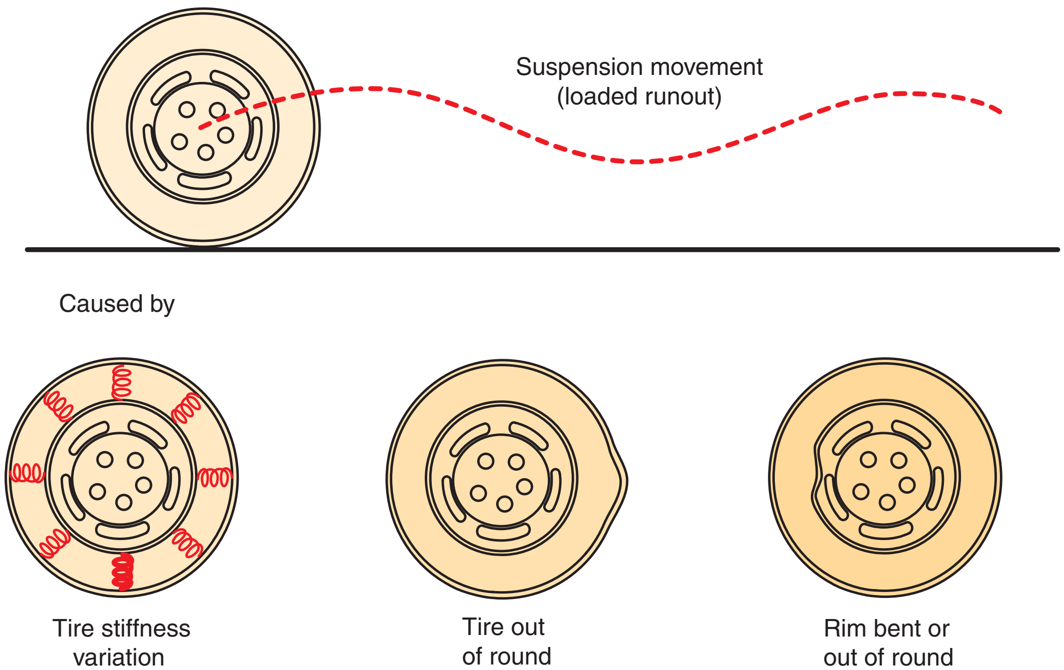

FIGURE 4-19 **Vertical tire and wheel vibrations caused by radial tire or wheel runout, or variation in tire stiffness.**

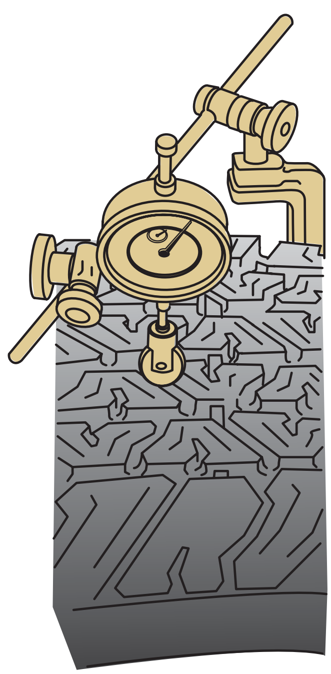
FIGURE 4-20 **Measuring tire radial runout.**

chalk mark from the highest point of maximum tire radial runout, the tire may be rotated 180° on the wheel to reduce radial runout. Tires or wheels with excessive runout are usually replaced.

Lateral tire runout may be measured with a dial indicator located against the sidewall of the tire. Excessive lateral runout causes the tire to waddle as it turns, and this waddling sensation may be transmitted to the passenger compartment (Figure 4-22). A chassis waddling

Side-to-side tire and chassis movement caused by excessive lateral tire runout may be called tire or chassis waddle.

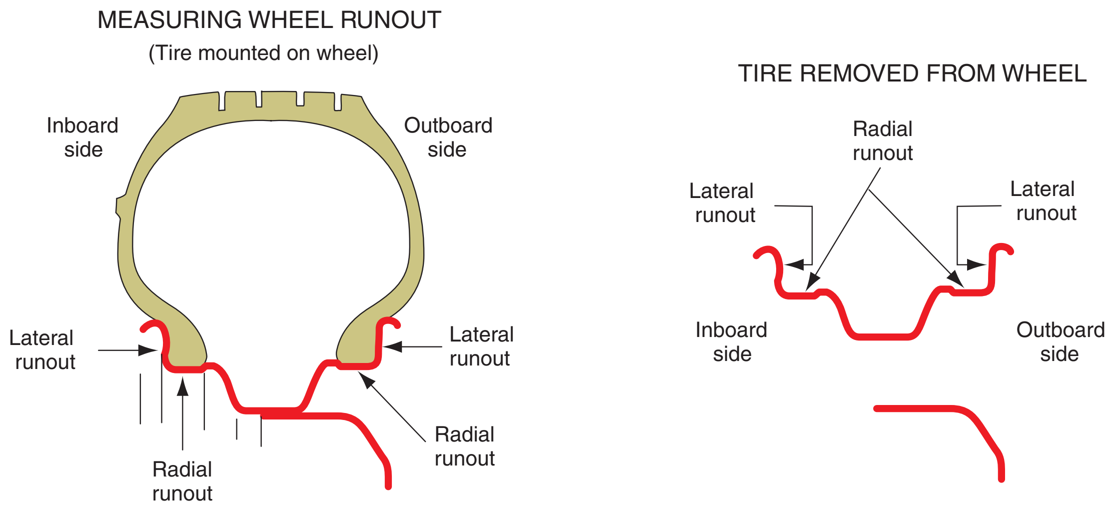

FIGURE 4-21 **Measuring wheel radial and lateral runout.**

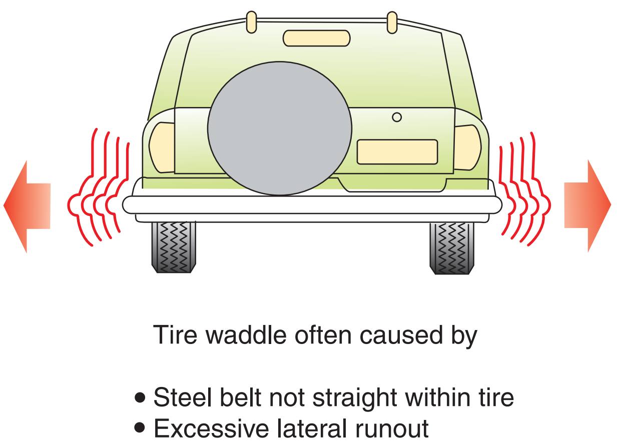

FIGURE 4-22 **Chassis waddling action caused by lateral tire or wheel runout, or a defective tire with a belt that is not straight.**

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action may also be caused by a defective tire in which the belt is not straight. If the lateral runout exceeds 0.050 in. (1.27 mm) off vehicle or 0.060 in. (1.52 mm) on vehicle, wheel shake problems will occur on the vehicle. Chalk mark the tire and wheel at the highest point of lateral runout. When the tire runout is excessive, the tire should be removed from the wheel, and the wheel lateral runout should be measured with a dial indicator positioned against the edge of the wheel as the wheel is rotated. Tires or wheels with excessive lateral runout should be replaced.

Tread Wear Measurement

On most tires, the **tread wear indicators** appear as wide bands across the tread when tread depth is worn to 1/16 in. (1.6 mm). Most tire manufacturers recommend tire replacement when the tread wear indicators appear across two or more tread grooves at three locations around the tire (Figure 4-23). If tires do not have wear indicators, a tread depth gauge may be used to measure the tread depth (Figure 4-24). The tread depth gauge reads in 32nds of an inch. Tires with 2/32 in. of tread depth or less should be replaced.

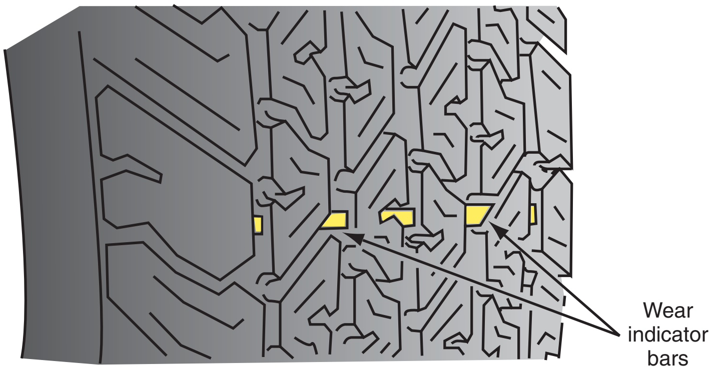

FIGURE 4-23 **Tire tread wear indicators.**

FIGURE 4-24 **Tread depth gauge.**

Preliminary Wheel Balancing Checks

These preliminary checks should be completed before a tire and wheel are balanced:

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1. Check for objects in the tire tread.
2. Check for objects inside the tire.
3. Inspect the tread and sidewall.
4. Check the inflation pressure.
5. Measure the tire and wheel runout.
6. Check the wheel bearing adjustment.
7. Check for mud collected on the inside of the wheel and wash the tire and wheel assembly.
8. Inspect the wheel rim for damage and excessive rust.

WARNING: On many wheel balancers, the tire and wheel are spun at high speed during the dynamic balance procedure. Be sure that all wheel weights are attached securely, and check for other loose objects on the tire and wheel, such as stones in the tread. If loose objects are detached from the tire or wheel at high speed, they may cause serious personal injury or property damage.

WARNING: On the type of wheel balancer that spins the tire and wheel at high speed during the dynamic balance procedure, always attach the tire-and-wheel assembly securely to the balancer. Follow the equipment manufacturer's recommended wheel mounting procedure. If the tire-and-wheel assembly becomes loose on the balancer at high speed, serious personal injury or property damage may result.

WARNING: Prior to spinning a tire and wheel at high speed on a wheel balancer, always lower the protection shield over the tire. This shield provides protection in case anything flies off the tire or wheel.

All of the items on the preliminary check list influence wheel balance or safety. Therefore, it is extremely important that the preliminary checks be completed. Since a tire-and-wheel assembly is rotated at high speed during the dynamic balance procedure, it is very important that objects such as stones be removed from the treads. Centrifugal force may dislodge objects from the treads and cause serious personal injury. For this reason, it is also extremely important that the old wheel weights be removed from the wheel prior to balancing and the new weights attached securely to the wheel during the balance procedure.

Follow these preliminary steps before attempting to balance a wheel and tire:

1. When off-car wheel balancers are used, the tire and wheel must be removed from the vehicle and installed on the balancer. All mud, dust, and debris must be washed from the wheel after it is removed.
2. Objects inside a tire, such as balls of rubber, make balance impossible. When the tire-and-wheel assembly is mounted on the balancer, be absolutely sure that the wheel is securely tightened on the balancer. As the tire is rotated slowly, listen for objects rolling inside the tire. If such objects are present, they must be removed prior to wheel balancing.
3. The tire should be inspected for tread and sidewall defects before the balance procedure. These defects create safety hazards, and they may influence wheel balance. For example, tread chunking makes the wheel balancing difficult.

Tire Inflation Pressure

A tire depends on correct inflation pressure to maintain its correct shape and support the vehicle weight.

Excessive inflation pressure causes the following problems:

1. Excessive center tread wear (Figure 4-25)
2. Hard ride
3. Damage to tire carcass

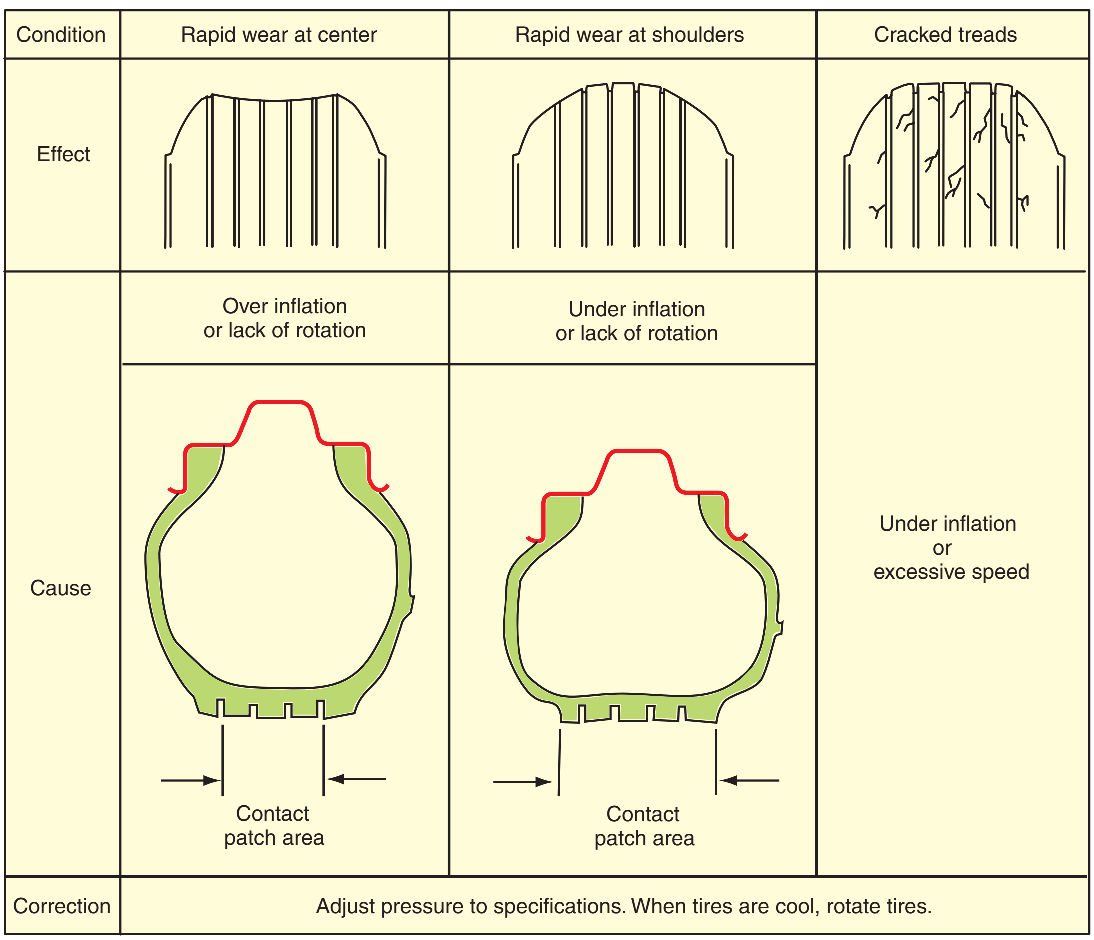


FIGURE 4-25 **Tire tread wear caused by underinflation or overinflation.**

When tires are underinflated, the following problems will be evident:

1. Excessive wear on each side of the tread (Figure 4-23)
2. Hard steering
3. Wheel damage
4. Excessive heat buildup in the tire and possible severe tire damage with resultant hazardous driving

The tires should be inflated to the car manufacturer's recommended pressure prior to the balance procedure. Loose wheel bearings allow lateral wheel shaking and simulate an imbalanced wheel condition when the vehicle is in motion. Therefore, wheel bearing adjustments should be checked when wheel balance conditions are diagnosed.

Static and Dynamic Wheel Balance Procedure

The off-vehicle electronic wheel balancer is presently the most common type in use (Figure 4-26). When using this type of wheel balancer, each tire and wheel assembly is removed from the vehicle and installed on the wheel balancer. A special cone centers the wheel rim on the balancer shaft, and a large nut retains the wheel and tire assembly on the balancer. Tire and wheel assemblies must always be mounted on the balancer using the service procedures recommended by the balancer manufacturer. Most electronic wheel balancers have an electric motor that spins the tire and wheel assembly at moderate speed during the balance procedure. A safety cover on the balancer must be lowered over the tire and wheel assembly when the tire and wheel assembly is spun on the balancer. This hood protects the technician from any debris that might be dislodged from the tire tread. On some electronic wheel balancers, the tire and wheel assembly is spun by hand during the balance procedure.

SPECIAL TOOLS
Off-car electronic wheel balancer

After the tire and wheel assembly is mounted properly on the balancer, the technician must enter the wheel diameter, wheel width, and rim offset in the balancer computer. A special caliper may be used to measure the wheel width. A special tool on the balancer may be extended so it contacts the flange on the side of the wheel rim next to the balancer.

FIGURE 4-26 **Electronic wheel balancer.**

Static balance refers to the balance of a stationary wheel.

Dynamic wheel balance refers to proper balance of the tire and wheel assembly during tire and wheel rotation.

SERVICE TIP: Some wheel rims such as magnesium rims require the use of stick-on wheel weights.

SERVICE TIP: Wheel weights are rated in ounces or grams.

A **heavy spot** is a location a tire with excessive weight.

This tool provides the required wheel offset measurement that indicates the position of the wheel on the balancer shaft. An electronic wheel balancer performs **static balance** and **dynamic wheel balance** calculations simultaneously. The following is a typical wheel balance procedure:

1. Complete all the preliminary balance checks mentioned previously in this chapter.
2. Be sure the tire and wheel assembly is mounted on the balancer using the balancer manufacturer's recommended mounting procedure.
3. Use a pair of wheel weight pliers to remove all the old wheel weights from the wheel rim (Figure 4-27).
4. Enter the wheel diameter, width, and offset in the balancer computer.
5. Be sure the safety hood is lowered over the tire and wheel assembly, and activate the balancer control to spin the wheel and tire assembly.
6. Operate the balancer brake to slow and stop the wheel, and observe the balancer display screen to determine the size and location of wheel weight(s) required on the wheel rim.
7. Install the correct wheel weights in the locations indicated on the balancer screen. Use that hammer head on the wheel weight pliers to install the weights.
8. Spin the wheel again on the balancer; the balancer screen should indicate a balanced tire and wheel assembly.
9. Remove the wheel and tire assembly from the balancer, and install this assembly on the vehicle using the alignment marks placed on the tire wheel and hub stud prior to wheel removal.
10. Tighten the wheel lug nuts to the specified torque in the proper sequence.

On some pre electronic wheel balancers, a static balance procedure is performed by allowing the wheel and tire assembly to rotate by gravity on the wheel balancer. A **heavy spot** in the tire rotates the tire and wheel assembly until the heavy spot is at the bottom. The necessary wheel balance weights were then added at the top of the wheel 180° from the heavy spot. Equal wheel weights were installed on each side of the wheel (Figure 4-28). If a wheel has dynamic unbalance, and the heavy spot is on the outside edge of the tire tread, the correct size of wheel weight is installed on the rim 180° from the heavy spot (Figure 4-29). Improper static or dynamic wheel balance causes cupped tire tread wear and bald spots on the tread (Figure 4-30). Incorrect static wheel balance results in wheel tramp, and improper dynamic wheel balance causes wheel shimmy. When using an electronic wheel balancer, the

FIGURE 4-27 **Wheel weights are removed and installed with special wheel weight pliers.**

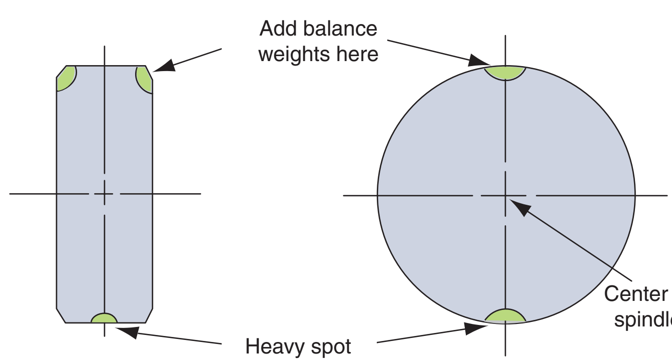


FIGURE 4-28 **Static wheel balance procedure.**

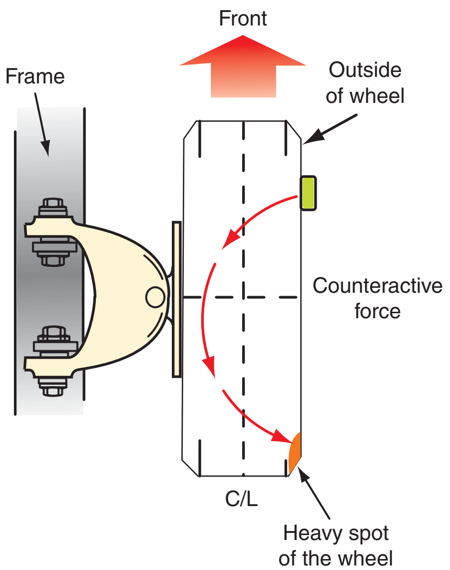


FIGURE 4-29 **Dynamic wheel balance procedure with heavy spot on the outside edge of the tread.**

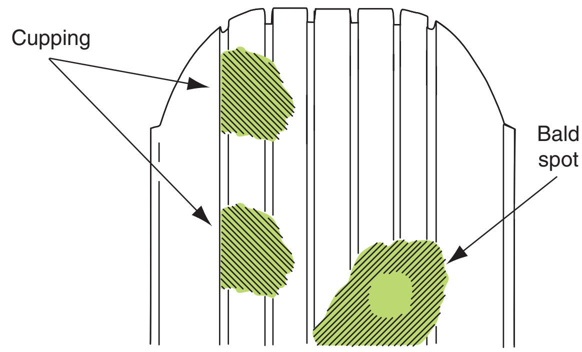


FIGURE 4-30 **Cupped tire tread wear with bald spots on the tread caused by improper static or dynamic wheel balance.**

technician does not have to determine the wheel weight size or location because the balancer provides this information to the technician.

The Center for Environmental Health (CEH) in California together with Chrysler Group and three major wheel weight manufacturers reached an agreement to end the use of lead wheel weights in California by December 31, 2009. It is estimated that lead wheel weights cause 500,000 lbs of lead to be placed in the environment each year from wheel weights breaking off vehicle wheels. Lead wheel weights will be replaced with a metal or material that is more environmentally friendly. Be sure you are installing the type of wheel weights required by the legislation in your state.

Photo Sequence 6 illustrates a typical off-car wheel balance procedure.

Electronic Wheel Balancers with Lateral Force Measurement (LFM) and Radial Force Variation Capabilities

Improper wheel balance is only one cause of wheel vibration. Wheel vibration may also be caused by tire and/or wheel runout or stiffness variation in the tire sidewalls. Some wheel balancers now have the capability to measure wheel and tire runout and stiffness or force variation in the tire sidewalls. Tire and wheel rim runout may be measured with a dial indicator, but this operation is very time consuming. Many tires marketed today have a paint dot or mark on the sidewall that indicates either the high side or low side of the force variation in the tire. This paint dot is aligned with the valve stem when the tire is mounted on the wheel rim. Using this system, the technician is assuming the paint dot is placed at the high point of radial force, and the valve stem hole is at the low point of runout on the rim. However, this is not always true, and a tire mounted with this tire position in relation to the wheel rim may cause vibration even though it is properly balanced. Other tires may have a slight conicity problem that causes steering pull on the vehicle.

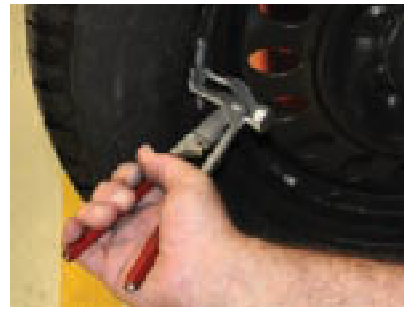
An electronic wheel balancer with radial force variation capabilities has a roller that is forced against the tire tread with considerable force during the balance procedure. This type of balancer provides wheel balance following the usual procedure. The roller forced against the tire allows the balancer to measure tire conicity that results in lateral force and steering

PHOTO SEQUENCE 6

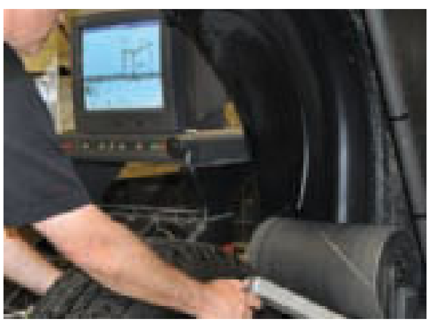
Typical Off-Car Wheel Balancing Procedure

P6-1 **Complete all the preliminary wheel balance checks.**

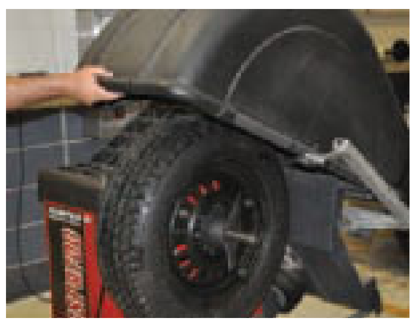
P6-2 **Follow the wheel balancer manufacturer's recommended procedure to mount the wheel-and-tire assembly securely on the electronic wheel balancer. Some wheel balancers have a centering check in the programming procedure. If the tire and wheel are not mounted properly, tire and wheel balance will be inaccurate.**



P6-3 **Use a pair of wheel weight pliers to remove all the wheel weights from the wheel rim.**



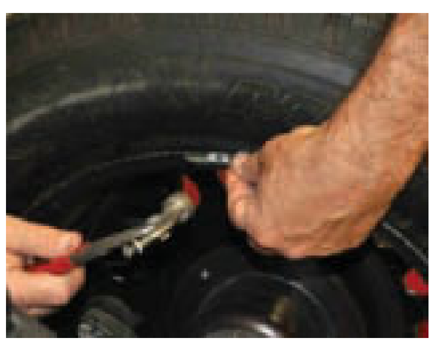
P6-4 **Enter the wheel diameter, width, and offset on the wheel balancer screen.**



P6-5 **Lower the safety hood over the wheel and tire on the wheel balancer.**

P6-6 **Activate the wheel balancer control to spin the wheel-and-tire assembly.**

P6-7 **Stop the wheel-and-tire assembly. Observe the wheel balancer display screen to determine the correct size and location of the required wheel weights.**



P6-8 **Install the correct size wheel weights in the location(s) indicated on the wheel balancer screen.**

P6-9 **Activate the wheel balancer control to spin the wheel again, and observe the wheel balancer display to confirm that it indicates a balanced wheel-and-tire assembly.**

P6-10 **Stop the wheel, lift the safety hood, and remove the wheel-and-tire assembly from the balancer.**

pull (Figure 4-31). As each tire and wheel assembly is balanced, the balancer display indicates a number for each assembly (Figure 4-32). The balancer display also indicates the position on the vehicle where each numbered tire and wheel assembly should be installed to provide the least amount of steering pull and the best straight-ahead steering stability (Figure 4-33). The wheel balancer with LFM capabilities provides a much faster and more accurate method for diagnosing and correcting steering pull caused by tire conicity compared to the previous method of rotating tires to try and correct this problem.

The balancer also measures lateral and radial tire and wheel runout, and indicates if the runout is rim or tire related. This type of balancer also measures force variation in the tire (Figure 4-34). The balancer display indicates the amount of tire and tire and wheel assembly road force. The display also indicates the necessary tire and wheel service to correct the excessive road force. Using the balancer display, a chalk mark may be placed on the tire at the location of the high force variation, and a second chalk mark on the rim 180° away from the first chalk mark (Figure 4-35). The tire and wheel assembly may be installed on a tire changer, and the rim may be rotated in relation to the tire to correct the force variation.

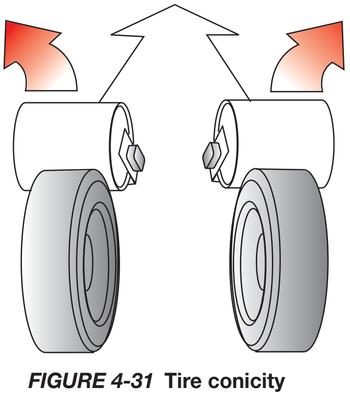


FIGURE 4-31 **Tire conicity sensed by the roller on the balancer causes lateral force and steering pull.**

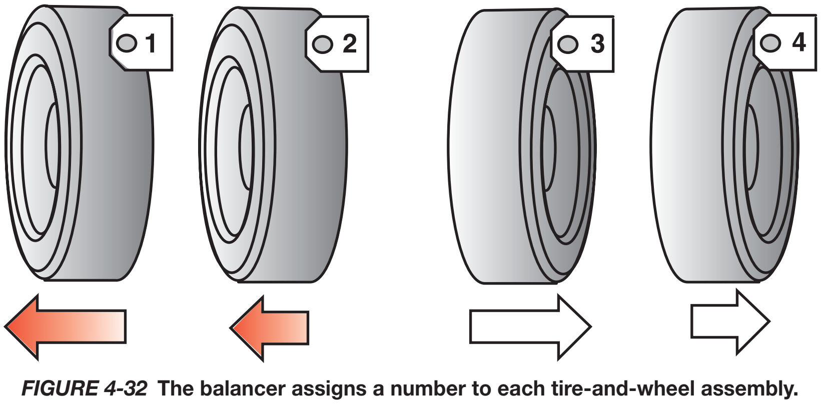


FIGURE 4-32 **The balancer assigns a number to each tire-and-wheel assembly.**

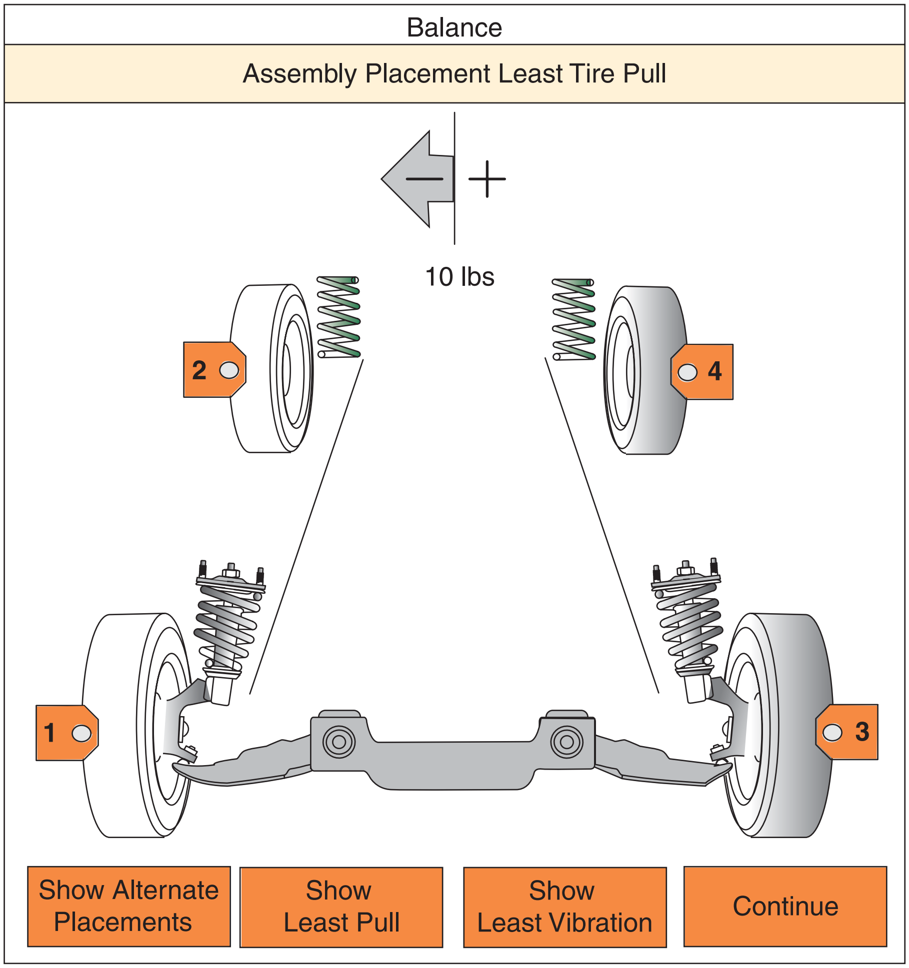


FIGURE 4-33 **The balancer display indicates the location on the vehicle where each numbered tire should be installed.**

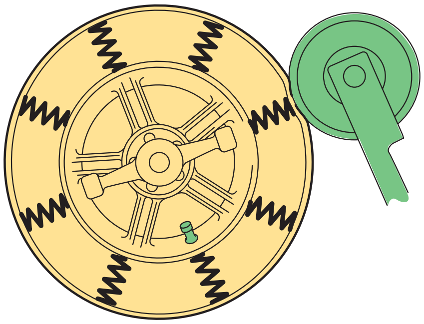


FIGURE 4-34 **The roller on the balancer senses force variation in the tire.**

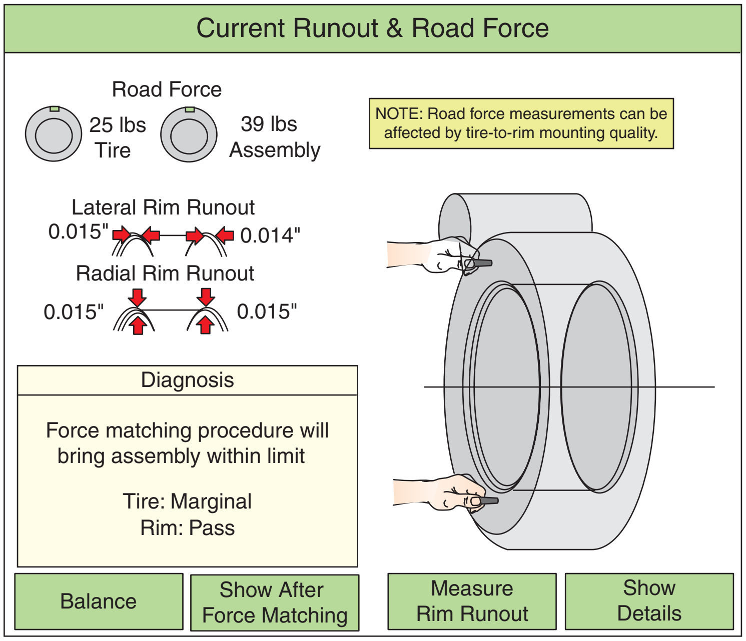


FIGURE 4-35 **The balancer display indicates the necessary correction for excessive force variation.**

On-Car Wheel Balancing

On-car wheel balancers contain a drum driven by an electric motor. This drum is positioned against the tire on the vehicle, which allows the electric motor to rotate the wheel. Many on-car balancers have a strobe light with a meter and an electronic vibration sensor. Off-car wheel balancing and on-car wheel balancing are a complementary combination for fine-tuning wheel balance. For example, a wheel vibration problem may still exist after an off-car balance procedure. If this problem occurs, the on-car balancer may be used to correct the problem. The on-car balance procedure corrects imbalance problems in all rotating components, including brake drums or rotors.

SPECIAL TOOLS
On-car wheel balancer

When a front wheel on a rear-wheel-drive car is balanced, use this procedure:

1. Perform the preliminary checks listed previously in this chapter.
2. Raise the wheel being balanced 5 in. (12 cm) off the floor and be sure the chassis is supported on safety stands so the wheel drops downward.
3. Install the electronic vibration sensor between the lower control arm and the floor.
4. Chalk mark a reference mark on the outer sidewall of the tire.
5. Spin the wheel just fast enough to produce vibration on the front bumper.
6. When vibration causes strobe light flashing, move the balancer drum away from the tire and allow the tire to spin freely.
7. Shine the strobe light around the tire sidewall and note the chalk-mark position.
8. Note the pointer position on the meter.
9. Use the balancer's brake plate to slow and stop the wheel.
10. Rotate the wheel until the chalk mark is in the exact position where it appeared under the strobe light. The heavy spot is now at the bottom of the wheel and the balancing weight should be attached 180° from the heavy spot. Install the amount of weight indicated on the meter.
11. Spin the wheel again (Figure 4-36). If the wheel balance is satisfactory, the meter pointer will read in the balanced position. When the pointer does not indicate a balanced wheel, shine the strobe light on the tire sidewall. If the installed wheel weight is at the 12 o'clock position, additional weight is required, whereas the 6 o'clock weight position indicates excessive weight. A 3 o'clock or 9 o'clock weight position may be corrected by moving the weight 1 in. (2.5 cm) toward the 12 o'clock position.

Additional on-car wheel balancer precautions include:

1. Do not spin the wheel at excessive speeds.
2. Do not spin the front wheels on a front-wheel-drive vehicle with the floor jack under the chassis and the suspension dropped downward. Under this condition, severe angles

FIGURE 4-36 **On-car wheel balancer.**

CAUTION:
On a rear-wheel-drive vehicle when a rear wheel is rotated with an on-car balancer, do not allow the speed indicated on the speedometer to exceed 35 mph (56 km/h), because the wheel speed is much faster than the speed indicated on the speedometer.

exist in the front drive axle joints, and these joints may be damaged if the wheels are rotated with the balancer. Place the floor jack under the lower control arm to raise the wheel.

Rear Wheel Balancing

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If an on-car balancer is used on the rear wheels of a rear-wheel-drive car, the technician must determine if the vehicle has a conventional or a limited slip differential. With the transmission in park, or in gear with a manual transmission, rotate one rear wheel by hand. If the vehicle has a limited slip differential, the rear wheels will not rotate, whereas a free-turning wheel indicates a conventional differential.

When the vehicle has a conventional differential, use the same front wheel balance procedure on the rear wheels. Raise only the wheel to be balanced from the floor, and do not allow the speed indicated on the speedometer to exceed 35 mph (56 km/h). When the other rear tire is resting on the floor, the speed of the wheel being balanced is 70 mph (112 km/h).

If the vehicle has a limited slip differential, proceed as follows for on-car rear wheel balancing:

1. Raise the vehicle and place safety stands under the frame to support the vehicle weight.
2. Lift the rear axle housing with a floor jack to reduce the universal joint angles, but do not take the vehicle weight off the safety stands.
3. Remove the wheel that is not being balanced. Install and torque the wheel nuts on the brake drum to hold the drum in place.
4. Balance the opposite wheel using the same procedure as for the front wheels.
5. Leave the balanced wheel on the vehicle and install and balance the other wheel. Be sure to torque the wheel nuts properly. Do not allow rear wheel speed to exceed 55 mph (90 km/h) on the speedometer.

Vibration Diagnosis

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The technician must have a logical sequence for vibration diagnosis. This problem may be diagnosed using the same basic diagnostic procedure that is used for diagnosing defects in other parts of the vehicle.

A basic diagnostic procedure follows:

1. Question the customer regarding the vibration problem, and obtain as much information as possible from this source.
2. Be sure the complaint is identified. Road test the vehicle if necessary.
3. Think of the possible causes of the vibration.
4. Perform the necessary inspection and test procedures to locate the cause of the vibration.
5. Complete the necessary repairs to correct the problem(s) identified in the inspection and test procedures.
6. Be sure the original customer complaint is eliminated. If necessary, road test the vehicle.

When questioning the customer regarding the vibration problem, the technician should obtain the answers to these questions:

1. At what vehicle speed is the vibration most noticeable?
2. Is the vibration felt in the vehicle, and in what area of the vehicle is the vibration present? (For example, left front, right rear, under the vehicle floor.)
3. Can the customer hear the vibration?
4. Does engine load, such as hard acceleration, affect the vibration?
5. Does vehicle load, such as the number of passengers or weight in the trunk, affect the vibration?

6. Does the vibration occur in all transmission gear ranges?
7. When did the customer first notice the vibration? Did the vibration occur after some other service work was performed on the vehicle?

Basic Road Test

The purpose of a road test is to verify the vibration complaint and determine any operating conditions under which the vibration changes or is eliminated. A road test should also determine if the vibration is related to engine speed or vehicle road speed. During any road test for vibration diagnosis, if the vehicle does not have an in-dash tachometer, connect a tachometer to the ignition system, and install the leads through one of the windows so the tachometer may be placed in view of the driver. Connect the power cord from an **electronic vibration analyzer (EVA)** to the cigarette lighter socket, and attach the EVA vibration sensor to the area where the suspected vibration is located (Figure 4-37).

The **electronic vibration analyzer (EVA)** is a tester that helps to locate the source of a vibration.

When it is determined that the vibration is related to engine speed or vehicle road speed, the technician has to perform special test procedures to locate the cause of the vibration in one of these areas:

1. Engine, engine or transmission mount, clutch disc and pressure plate (manual transmission), flexplate and torque converter (automatic transmission)
2. Propeller shaft, transmission output shaft, differential pinion flange (rear-wheel-drive vehicles), front drive axles (front-wheel-drive vehicles)
3. Tires, wheels, hubs, and brake rotors

Special Road Tests

Slow Acceleration Test. All of the special road tests help the technician to locate the cause of the vibration. A tire and wheel inspection should be completed before any road test. Defects discovered during the tire inspection may explain the cause of the vibration that occurs during a road test.

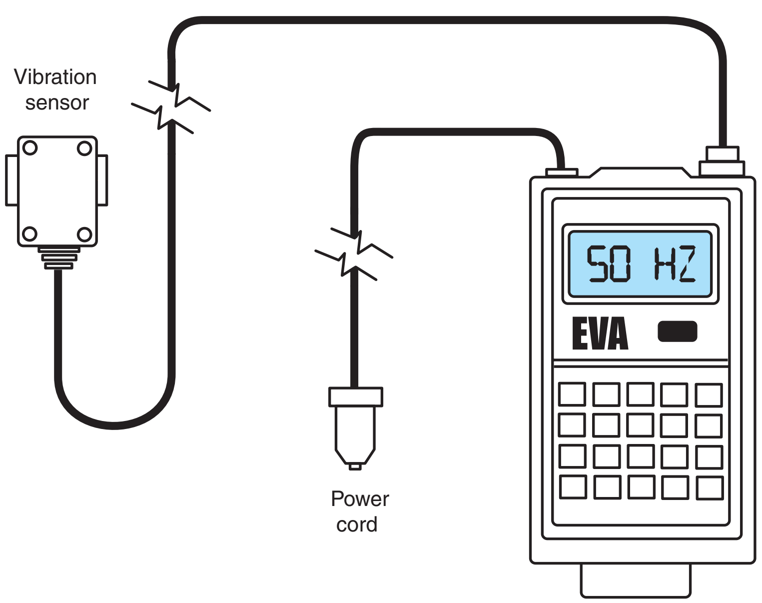


FIGURE 4-37 **Electronic vibration analyzer (EVA).**

Inspect the tires and wheel for these defects:

1. Check the inflation pressure in each tire.
2. Check for unusual tire wear such as cupping, excessive tread wear, and flat or bald spots. Inspect the tire sidewalls and tread area for bulges and ply separation. These tire defects may cause vibration, slapping noise, and tire growl or howl.
3. Inspect the rims for bends, damage, and excessive corrosion.

Perform the **slow acceleration test** on a smooth level road. During this test, accelerate the vehicle from a stop to legal highway speed. Check for any vibration that matches the customer's description. If any vibration is present, record the frequency vehicle speed and engine speed when the vibration occurred.

Neutral Coast-Down Test. Perform the **neutral coast-down** test on a smooth, level road. Accelerate the vehicle to a speed slightly higher than the speed at which the vibration occurs. Shift the transmission into neutral and allow the vehicle to coast down through the speed range at which the vibration occurs. If the vibration still occurs in neutral, the vibration is vehicle-speed sensitive, and the engine, propeller shaft, flexplate, and torque converter have been eliminated as causes of the vibration. When the vibration occurs with the transmission in neutral, the vibration diagnosis should concentrate on the drive axle assemblies and the tire-and-wheel assemblies. Off-car or on-car balance procedures are performed to correct balance problems in brake drums or rotors and tires and wheels.

Downshift Test. To complete the **downshift test**, drive the vehicle on a smooth, level road at the speed when the vibration is present. Note the engine rpm. Decelerate and reduce the vehicle speed until the vibration is no longer present. Manually downshift the transmission into the next lowest gear, and accelerate the vehicle until the engine is running at the previously recorded rpm. If the vibration returns at the same engine rpm, the engine, propeller shaft, flexplate and torque converter (automatic transmission) or clutch disc and pressure plate (manual transmission) are the most likely causes of the vibration.

Neutral Run-Up Test. Perform the **neutral run-up test** when the customer complains about vibration at idle speed or as a follow-up to the downshift test. To perform the neutral run-up test, slowly increase the engine rpm from idle. Note the engine rpm and frequency at which vibration occurs. If vibration occurs, the cause of the vibration is related to the engine, flexplate and torque converter (automatic transmission) or clutch disc and pressure plate (manual transmission).

Brake Torque Test. The **brake torque test** may be used to identify engine vibrations that were not present during the downshift and neutral run-up tests. This test may also be used when diagnosing vibrations that are sensitive to engine load.

To perform the brake torque test, follow this procedure:

1. Firmly apply the parking brake.
2. Block the front wheels.
3. Firmly apply the brake pedal.
4. Shift transmission into drive.
5. Slowly increase the engine speed to 1,200 rpm and check for vibrations.
6. Note the engine rpm when vibration occurred.

CAUTION:
Do not increase the engine rpm above 1,200, and limit this test to 10 seconds to protect the transmission from overheating.

If engine vibrations occur during the brake torque test, but they did not occur during the downshift and neutral run-up tests, the engine and/or transmission mounts are a prime suspect for the cause of the vibration.

Steering Input Test. The **steering input test** may be performed to diagnose vibrations in suspension components. To perform this test, drive the vehicle through sweeping turns at the speed when the vibration occurs. Drive the vehicle when turning in one direction and then perform some turns in the opposite direction. If the vibration changes during these turns, the vibration is likely caused by defective wheel bearings, tire tread, or front drive axle shafts and joints.

Standing Acceleration Test. The **standing acceleration test** is used to diagnosis a vibration that may be called a launch shudder. To perform the standing acceleration test bring the vehicle to a complete stop. Place the transmission in drive and remove your foot from the brake pedal. Accelerate the vehicle to 30 to 40 mph (48 to 64 km/h), and check for vibrations that match the customer's complaint. If a shudder-type vibration occurs during the test, the cause of this vibration could be incorrect curb riding height, defective front drive axle joints, defective engine or transmission mounts, or faulty exhaust hangers or mounts.

Vibration Diagnosis with the Electronic Vibration Analyzer (EVA)

The EVA is helpful in locating the source of vibration problems.

Follow these steps to connect the EVA:

1. Be sure the correct software cartridge is securely installed in the bottom of the EVA.
2. Connect the vibration sensor cord to input A or B on the EVA. Position the release button facing downward on the lower side of this connector. Push the connector into the input port until the connector clicks and locks in place.
3. Follow these steps to perform the sensor calibration procedure:
   a. Lay the sensor on a flat stationary surface, and be sure the side of the sensor marked UP is facing upward.
   b. Plug the EVA power cord into a 12 V power supply, such as the cigarette lighter.
   c. Press the "up" arrow key.
   d. Press number 2 on the key pad three times until the word BURNING appears, followed by a request to turn the sensor over.
   e. Turn the sensor over and press any key on the keypad to begin calibration. The calibration procedure takes approximately 20 seconds, and the display returns to the active mode when calibration is completed.
4. Two vibration sensors can be connected to ports A and B on the EVA at the same time, and the A/B button on the tester can be used to switch from one sensor to the other. Place the sensor(s) on any component that is suspected of being a vibration source. Each sensor has a 20-ft. cord, so it may be placed anywhere on the vehicle. Each sensor contains a magnet for attachment to metal surfaces. For attachment to nonmagnetic surfaces, use putty or a hook and loop fastener. Vibrations are usually felt in an up-and-down direction. Because the vibration sensor is directionally sensitive, this sensor must be mounted on the lower part of the suspected component with the marking on the sensor facing upward (Figure 4-38). When repeating a vibration test on the same component, always be sure the vibration sensor is mounted in the exact same location.

CAUTION:
When installing the sensor connector in the EVA input terminal, do not twist the sensor connector. Do not remove this connector when the EVA is in use. This action may damage the EVA.

Hertz or rpm are displayed on the left side of the EVA display. Either of these values may be selected by pressing the "RPM/Hertz" button on the tester. The selected value is displayed at

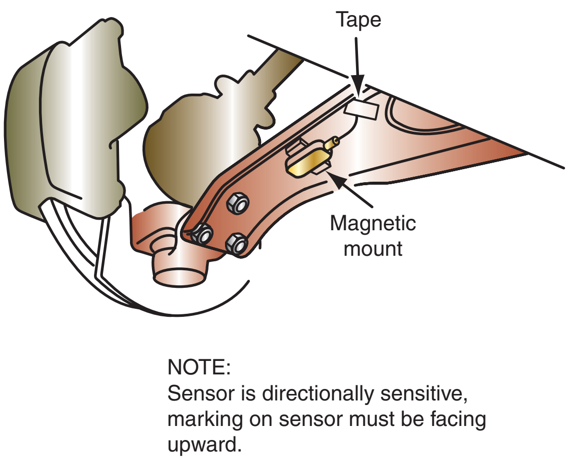


FIGURE 4-38 **Vibration sensor mounting.**

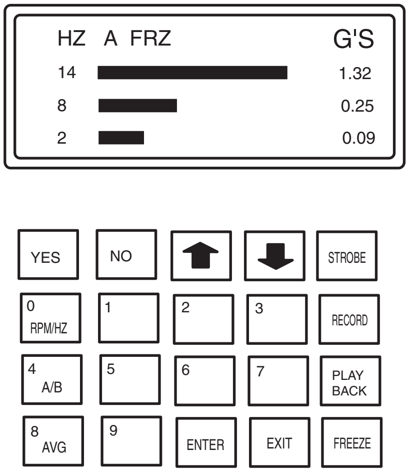


FIGURE 4-39 **Electronic vibration analyzer (EVA) display and keypad.**

the top of the left column on the display. A bar graph of the suspected source of the vibration is shown in the center of the display. When the AUTO mode is selected, the suspected vibration source is shown in the display. If the AUTO mode is not in use, the bar graph is indicated in the center of the display (Figure 4-39). The amplitude of each frequency indicated on the left of the screen is displayed on the right side of the screen. These amplitudes are displayed in Gs of acceleration force. Higher amplitudes indicate stronger vibration forces. The EVA displays up to three of the most dominant input frequencies in descending order of amplitude strength.

The technician may press the averaging (AVG) button to select this mode. In the AVG mode, the EVA displays the average of multiple vibration readings taken over a period of time. The EVA is usually operated in the AVG mode to minimize distractions caused by a sudden vibration that is not related to the main vibration source. These distractions could be caused by the vehicle wheels striking road irregularities. When the EVA is operating in the AVG mode and the Auto Mode, "A" is displayed along the top of the screen. The AUTO mode is designed to be used with the vibration diagnosis tables in the appropriate service manual. If the EVA is operating in the AVG mode and the MANUAL mode, AVG is shown at the top of the screen. When the EVA is operating in the non-AVG mode and the AUTO mode, "I" is indicated at the top of the display. The top row on the display also indicates "A" or "B," representing the vibration sensor input port.

When the FREEZE button is pressed, the EVA displays FRZ on the top line of the display. In this mode the EVA will store data for a short time period when the RECORD button is pressed during various vibration tests. The technician may press the PLAY BACK button to display the recorded data. The technician presses the EXIT button to return the EVA to normal operation.

The EVA has a strobe light trigger wire that may be used with an inductive pickup timing light to balance rotating components such as propeller shafts.

Calculating Vibration Frequencies of Various Components

Calculating Tire/Wheel Frequency. The first step in calculating tire/wheel frequency is to divide the vehicle speed by five-mile-per-hour increments. There are 12 increments of 5 miles per hour, if the vehicle speed is 60 mph. The next step is to use the chart in Figure 4-40 to determine how many times a wheel and tire rotate per second at 5 mph. As indicated in this chart, if the tire size is 195/70/14, the tires revolve at 1.17 times per second for every 5 mph of vehicle speed. To calculate the tire/wheel frequency at 60 mph, multiply the number of five-mile-per-hour increments, 12, by the number of times the tire and wheel revolve in one second per 5 mph increment, 1.17. Therefore we have the calculation 12 × 1.17 = 14.04, and this

Tire Size	Tire Frequency at 5 mph	Tire Size	Tire Frequency at 5 mph
P145/80/13	1.31	215/70/15	1.08
155/80/13	1.27	215/75/15	1.05
175/65/14	1.26	215/75/16	1.01
185/65/14	1.23	215/85/16	0.95
185/70/14	1.20	220/75/15	1.03
185/75/14	1.16	225/45/17	1.16
195/60/15	1.20	225/55/17	1.08
195/65/15	1.16	225/60/16	1.09
195/70/14	1.17	225/70/15	1.06
195/75/14	1.13	225/70/16	1.02
195/75/15	1.09	225/75/15	1.02
205/55/15	1.21	225/75/16	0.99
205/55/16	1.16	235/70/15	1.04
205/60/14	1.22	235/75/15	1.00
205/60/15	1.17	235/75/16	0.97
205/65/15	1.14	245/70/15	1.02
205/70/14	1.14	245/70/16	0.98
205/70/15	1.10	245/75/16	0.95
205/75/14	1.11	275/40/17	1.13
205/75/15	1.07	295/40/20	0.99
215/50/17	1.14	335/35/17	1.10
215/55/16	1.14	30X9.5/15	0.98
215/65/15	1.11	31X10.5/15	0.95
215/65/16	1.07		

FIGURE 4-40 **Tire/wheel frequencies.**

size of tire and wheel on a vehicle traveling at 60 mph produces a vibration of approximately 14 hertz (Hz). With a vibration sensor attached to the lower control arm, if the EVA displays a vibration of 14 Hz, the tire and wheel mounted on the knuckle attached to the control arm has a vibration problem. This vibration problem could also be caused by a rotor or hub.

With a vibration of 14 Hz, a second-order vibration is 28 Hz, a third-order vibration is 42 Hz, and a fourth-order vibration is 56 Hz. On a front-wheel-drive vehicle, a worn constant velocity drive axle joint may cause a vibration in the fifth order of the tire/wheel vibration, and a defective tripod drive axle joint may result in a vibration of the third order of the tire/wheel vibration. On a rear-wheel-drive-vehicle if the tire/wheel frequency is 14 and the rear axle ratio is 3.42:1, the frequency of the drive shaft is $14 \times 3.42 = 47.88$.

Calculating Engine and Engine Firing Frequency. To calculate the engine frequency, divide the engine rpm by 60 seconds per minute. For example, if the engine rpm is 3,000, the engine frequency is $3{,}000 \div 60 = 50$ revolutions per second, or 50 Hz. To determine the engine firing frequency, divide the number of engine cylinders by two, and multiply the answer by the engine frequency. Let us assume we are working on a V6 engine running at 3,000 rpm. Divide the number of cylinders by two, and so $6 \div 2 = 3$. Then multiply this answer by the engine frequency of 50 to calculate the firing frequency. Therefore, $3 \times 50 = 150$ engine firing frequency. Because a cylinder in a four-cycle engine expels exhaust only once every two revolutions, a single cylinder frequency is one-half the engine frequency. Therefore, in our example if the engine frequency is 50, a single cylinder frequency is 25. This is the frequency of exhaust pulses in a single cylinder and also the frequency of the camshaft that turns at one-half the engine speed.

Calculating Accessory Drive Frequencies. To calculate the frequency of the belt-driven accessories, divide the diameter of the crankshaft pulley by the diameter of the pulley on the

belt-driven accessory and multiply the answer by the engine frequency. Let us assume the we are still working on the engine in our previous example which is a V6 engine with a frequency of 50 running at 3,000 rpm. With a vibration sensor mounted on the engine the EVA displays a vibration of 160 Hz. The diameter of the crankshaft pulley is 8 inches, the diameter of the power steering pulley is 5 inches, the diameter of the A/C compressor pulley is 4.5 inches, and the diameter of the alternator pulley is 2.5 inches.

Therefore, we have the following calculations:

Power steering pump frequency: $8 \div 5 = 1.6 \times 50 = 80$

A/C compressor frequency: $8 \div 4.5 = 1.7 \times 50 = 85$

Alternator frequency: $8 \div 2.5 = 3.2 \times 50 = 160$

When we compare the vibration frequency displayed on the EVA to the belt-driven accessory frequencies, the alternator frequency matches the frequency on the EVA, indicating the alternator is the source of the vibration.

TABLE 4-1 **Tire and Wheel Diagnosis**

Problem	Symptoms	Possible Causes
Tire thump	Thumping noise while driving	Cupped tire treads Excessive radial tire or wheel runout Tire defects Improper wheel balance Variation in tire stiffness
Chassis waddling	Lateral rear chassis oscillations while driving	Excessive rear tire or wheel lateral runout
Steering pull	Steering pulls to one side while driving straight ahead	Tire conicity Unmatched tires side-to-side Improper wheel alignment angles
Wheel vibration	A vibration that occurs at certain speeds and may be felt on the steering wheel or throughout the chassis	Improper wheel balance Excessive lateral tire runout Variation in tire stiffness Tire defects
Excessive wear on tire treads	Cupped tire treads Wear on tread center Equal wear on tread edges	Improper wheel balance Overinflation Underinflation

Terms to Know

Antitheft locking wheel covers
Antitheft wheel nuts
Brake torque test
Downshift test
Dynamic wheel balance
Heavy spot
Lateral tire runout
Neutral coast down
Neutral run-up test
Ply separation
Radial runout
Slow acceleration test
Standing acceleration test
Static balance
Steering input test
Steering pull
Tire conicity
Tire rotation
Tire thump
Tire vibration
Tread wear indicators

CASE STUDY

A customer complains about severe front end waddling on a 2009 Cadillac STS equipped with steel-belted radial tires. The technician questions the customer further regarding this problem and learns that the problem occurs only after the car has sat overnight, and it lasts only for approximately six blocks when the customer starts driving the car.

The technician carefully checks all steering and suspension components, wheel bearing adjustment, and tire runout. No problems are found during these checks, and the technician asks the customer to leave the car in the shop overnight. The technician installs the front tires on the rear of the car and rotates the rear tires to the front, and the car is left in the shop overnight. A road test the next morning indicates rear end waddling, which proves the problem must be caused by a tire problem such as an improperly installed steel belt, since the tires were the only thing changed on the car. The technician installs and balances two new tires on the rear wheel rims, and installs these tires and wheels on the front of the car. The front tires and wheels were moved to the rear wheels. The customer reports later that the problem has been completely corrected.

ASE-Style Review Questions

1. While discussing a tire thumping problem:

   Technician A says this problem may be caused by cupped tire treads.

   Technician B says a heavy spot in the tire may cause this complaint.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While discussing a vehicle that pulls to one side:

   Technician A says that excessive radial runout on the right front tire may cause this problem.

   Technician B says that tire conicity may be the cause of this complaint.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. While discussing tire noise:

   Technician A says that tire noise varies with road surface conditions.

   Technician B says that tire noise remains constant when the vehicle is accelerated and decelerated.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. While discussing tire wear:

   Technician A says that static imbalance causes feathered tread wear.

   Technician B says that dynamic imbalance causes cupped wear and bald spots on the tire tread.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

5. While discussing on-car wheel balancing:

   Technician A says that during an on-car wheel balancing procedure on a rear wheel of a rear-wheel-drive car, the speed indicated on the speedometer should not exceed 65 mph (105 km/h).

   Technician B says that the speed indicated on the speedometer on this car must not exceed 35 mph (56 km/h).

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

6. A front tire has excessive wear on both edges of the-tire tread. The most likely cause of this problem is:

   A. Overinflation.
   B. Underinflation.
   C. Improper static balance.
   D. Improper dynamic balance.

7. When measuring radial tire and wheel runout, the maximum runout on most automotive tire-and-wheel assemblies should be:

   A. 0.015 in. (0.038 mm). C. 0.045 in. (1.143 mm).
   B. 0.025 in. (0.635 mm). D. 0.070 in. (1.77 mm).

8. When measuring lateral wheel runout with the tire demounted from the wheel, the maximum runout on most automotive wheels is:

   A. 0.020 in. (0.508 mm). C. 0.045 in. (1.143 mm).
   B. 0.030 in. (0.762 mm). D. 0.055 in. (1.397 mm).

9. All of these statements about improper wheel balance are true EXCEPT:

   A. Dynamic imbalance may cause wheel shimmy.
   B. Dynamic imbalance may cause steering pull in either direction.
   C. Static imbalance causes wheel tramp.
   D. Static imbalance causes rapid wear on suspension components.

10. When diagnosing wheel balance problems:

   A. Balls of rubber inside the tire have no effect on wheel balance.
   B. Loose wheel bearing adjustment may simulate improper static wheel balance.
   C. Improper dynamic wheel balance may be caused by a heavy spot in the center of the tire tread.
   D. After a tire patch is installed, the tire and wheel may be improperly balanced.

1. The owner of a rear-wheel-drive car with after-market alloy wheels says he has replaced the wheel bearings three times in the past two years. He wants to know why the bearings fail.

   Technician A says excessive radial runout of the wheel may be the cause of the problem.

   Technician B says excessive offset of the wheel may be the cause of the problem.

   Who is correct?

   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

2. A customer returns with recently purchased radial tires saying that the rear of the car feels like "it's riding on Jello™." All of the following could cause this problem EXCEPT:

   A. The radial belt of a rear tire is not straight.
   B. The wheel is improperly mounted.
   C. Excessive lateral wheel runout.
   D. Excessive radial tire runout.

3. A customer says the new tires he just purchased vibrate. The installer says he balanced the wheels and tires with a conventional electronic balancer before placing them on the car.

   Technician A says one of the tires may have a conicity problem.

   Technician B says one of the tires may have a force variation problem.

   Who is correct?

   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

4. After a set of radial tires is rotated, the customer returns saying he feels vibration and steering shimmy. To correct this problem, you should:

   A. Measure the lateral run out on each tire.
   B. Return the tires and wheels to their original positions.
   C. Check the wheel bearings.
   D. Balance the tires and wheels with an on-car balancer.

5. A customer says there is a "thumping" vibration in the wheels and an inspection of the tires shows the two front wheels have flat spots on the tire treads.

   Technician A says heavy spots in the tires may have caused this condition.

   Technician B says locking the wheels and skidding on pavement caused this condition.

   Who is correct?

   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

Name ______________________________ Date ____________________

Tire Dismounting and Mounting

Upon completion of this job sheet, you should be able to demount and mount tires.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task F-6: Dismount, inspect, and remount tire on wheel: Balance wheel and tire assembly (static and dynamic).

Tools and Materials

Tire changer

Tire-and-wheel assembly

Procedure

SERVICE TIP: The following is a generic tire demounting and mounting procedure.

1. Remove the valve core to release all the air pressure from the tire. Chalk mark the tire at the valve stem opening in the wheel so the tire may be re-installed in the same position to maintain proper wheel balance.

   Is all the air pressure released from the tire? ☐ Yes ☐ No

   Is the tire chalk marked at the valve stem location in the wheel?

   Instructor check ____

2. Guide the operating lever on the tire changer to unseat both tire beads. Are both tire beads unseated? Yes __________ No __________

3. Place the tire-and-wheel assembly properly on the tire changer. Is the tire-and-wheel assembly positioned properly on the tire changer? Yes __________ No __________

WARNING: Do not proceed to dismount the tire unless the tire-and-wheel assembly is securely attached to the tire changer. This action may cause personal injury.

4. Press the pedal on the tire changer that clamps the wheel to the changer. Is the wheel clamped properly to the tire changer? Yes __________ No __________

5. Lower the arm on the tire changer into position on the tire-and-wheel assembly. Is the tire changer arm positioned properly on the tire-and-wheel assembly? Yes __________ No __________

6. Insert the tire iron properly between the upper tire bead and the wheel. Be sure the tire iron is properly positioned. Depress the tire changer pedal that causes the wheel to rotate. This rotation moves the top bead out over the wheel. Is the top tire bead above the wheel rim? Yes __________ No __________

Task Completed

SERVICE TIP: Different makes of tire changers have various ways of tire bead seating on the wheel. Some tire changers have an air inflation ring that is positioned on top of the wheel and tire. Other tire changers have air jets in each clamping jaw that hold the wheel on the tire changer. Air pressure from these jets helps force the tire beads against the wheel sealing surfaces.

7. Lift the tire up and install the tire iron between the lower bead and the wheel. Be sure the tire iron is properly positioned. Depress the tire changer pedal that causes the wheel to rotate. This rotation moves the lower bead out over the wheel. Is the lower bead above the wheel rim? Yes ____________ No ____________

8. Remove the tire from the wheel.

9. Use a wire brush to remove rust and debris from the tire bead sealing areas on the wheel rim. Are the tire bead sealing areas on the wheel properly cleaned? Yes ____________ No____________

10. Apply rubber lubricant to both tire beads. Are both tire beads lubricated? Yes ____________ No ____________

11. Place the tire onto the wheel, and lower the tire changer arm into position. Depress the tire changer lever that causes the wheel to rotate. This action causes the lower tire bead over the wheel. Repeat this process to install the upper bead over the wheel. Is the tire properly installed on the wheel? Yes ____________ No ____________

WARNING: Do not proceed to mount the tire unless the wheel is securely attached to the tire changer. This action may cause personal injury.

12. Rotate the tire on the wheel so the chalk mark placed on the tire in step 8 is aligned with the valve stem opening in the wheel.

    Is the chalk mark on the tire aligned with the valve stem position?
    ☐ Yes ☐ No

☐

13. Install and tighten the valve core in the valve stem.

WARNING: When inflating a tire, do not stand or lean over the tire and wheel. If the tire bead comes off the rim or the rim cracks, personal injury may occur. When using a shop air hose to inflate the tire, install an extension on the air hose.

SERVICE TIP: Some tire changers have an air hose and air pressure gauge designed into the tire changer. On other tire changers a shop air hose must be used to inflate the tire.

14. Supply air to the air ring or air jets on the tire changer to move the tire beads outward against the wheel. Are the tire beads moved outward against the wheel?
    ☐ Yes ☐ No

15. Connect an air supply hose to the tire valve stem. When using a shop air hose, connect an extension to the air hose. Inflate the tire to the specified pressure.

    Specified tire pressure ____

    Actual tire pressure ____

Instructor's Response ____

____

____

Name ______________________ Date ______________

Tire and Wheel Runout Measurement

Upon completion of this job sheet, you should be able to measure radial and lateral tire and wheel runout.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task F-4: Measure wheel, tire, axle flange, and hub runout: determine necessary action.

SERVICE TIP: The tire and wheel may be installed on an off-car wheel balancer to measure tire and wheel runout.

Tools and Materials

Dial indicator
Tire-and-wheel assembly
Wheel balancer

Wheel diameter ______________________

Manufacturer and type of tire ______________________

Procedure

Task Completed

1. Mount the tire-and-wheel assembly properly on the wheel balancer and position a dial indicator against the center of the tire tread as the tire is rotated slowly to measure radial runout.
   Radial runout ______________
   Specified radial runout ______________
2. Mark the highest point of radial runout on the tire with chalk, and mark the valve stem position on the tire. ☐
3. If the radial tire runout is excessive, demount the tire, and check the runout of the wheel rim with a dial indicator positioned against the lip of the rim while the rim is rotated.
   Wheel radial runout ______________
   Specified wheel radial runout ______________
4. Use chalk to mark the highest point of radial runout on the wheel rim. ☐
5. If the highest point of wheel radial runout coincides with the chalk mark from the highest point of maximum tire radial runout, the tire may be rotated 180° on the wheel to reduce radial runout. Tires or wheels with excessive runout are usually replaced.
   Does the highest point of tire radial runout coincide with the highest point of wheel radial runout? ☐ Yes ☐ No

   Instructor's Response ______________________
   State the required action to correct excessive radial runout and the reason for this action.
   ____
   ____

Task Completed

6. Position a dial indicator located against the sidewall of the tire to measure lateral runout.

   Tire lateral runout ____________________

   Specified tire lateral runout ____________________

☐ 7. Chalk mark the tire and wheel at the highest point of lateral runout.

☐ 8. If the tire runout is excessive, the tire should be demounted from the wheel and the wheel lateral runout measured.

9. If the tire runout was excessive, measure the wheel lateral runout with a dial indicator positioned against the edge of the wheel as the wheel is rotated.

   Wheel lateral runout ____________________

   Specified wheel lateral runout ____________________

   State the required action to correct excessive wheel lateral runout and the reason for this action. ____

   ____

Instructor's Response ____

____

____

Name ______________________________ Date ____________________

Off-Car Wheel Balancing

Upon completion of this job sheet, you should be able to perform off-car wheel balancing procedures.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task F-6: Dismount, inspect, and remount tire on wheel. Balance wheel and tire assembly (static and dynamic).

Tools and Materials

Electronic off-car wheel balancer

Wheel weights

Tire and wheel

Wheel diameter ______________________________

Manufacturer and type of tire ______________________________

Describe the Vehicle Being Worked On:

Year __________ Make ______________ Model ____________________

VIN ____________________ Engine type and size ________________

Procedure

Task Completed

1. Wash mud and debris from the tire and wheel.
2. Mount the tire-and-wheel assembly on the wheel balancer with the wheel balancer manufacturer's recommended mounting components. ☐
3. Tighten the tire and wheel retaining nut on the wheel balancer to the specified torque.
   Tire and wheel retaining nut on the wheel balancer tightened to the specified torque?
   ☐ Yes ☐ No
   Instructor check ______________________________
4. Remove stones and other objects from the tire tread.
   Are stones and other objects removed from the tire tread? ☐ Yes ☐ No
   Instructor check ______________________________
5. Check for objects inside tire.
   Are there objects inside the tire? ☐ Yes ☐ No
   Instructor check ______________________________
6. Remove all the old wheel weights from the wheel.
   Are the old wheel weights removed? ☐ Yes ☐ No
   Instructor check ______________________________

Task Completed

7. Inspect the tread and sidewall.
   List defective tread and sidewall conditions. ______________________________
   ____
   List the types of tire tread wear and state the causes of this wear.
   ____
   ____
   Based on your inspection of the tire, list the required tire service.
   ____
   ____

8. Check tire inflation pressure.
   Tire inflation pressure ______________________________
   Specified tire inflation pressure ______________________________

9. Measure tire and wheel runout.
   Radial tire and wheel runout ______________________________
   Specified tire and wheel radial runout ______________________________
   Lateral tire and wheel runout ______________________________
   Specified lateral tire and lateral wheel runout ______________________________
   Recommended tire and wheel service. ______________________________
   ____

10. Lower the safety hood on the wheel balancer.
    Is the safety hood lowered? ☐ Yes ☐ No

11. Enter the required information on wheel balancer keypad, such as wheel diameter, wheel width, and wheel offset or distance.
    Is the required wheel information entered in the wheel balancer? ☐ Yes ☐ No
    Instructor check ______________________________

12. If the wheel balancer has a mode selector, select the desired balance mode.
    Balance mode selected ______________________________

13. Spin the wheel on the balancer, then apply the balancer brake to stop the wheel.

☐ 14. Observe the balancer display indicating the necessary amount of wheel weights and the required location of these weights. Install the required wheel weights in the locations indicated on the balancer. Be sure the wheel weights are securely attached to the rim.
    Are the wheel weight(s) securely attached to the rim at the locations indicated by the wheel balancer? ☐ Yes ☐ No
    Instructor check ______________________________

15. Spin the tire-and-wheel assembly on the the balancer again to be sure this assembly is properly balanced.
    Does the wheel balancer indicate proper wheel balance? ☐ Yes ☐ No
    If the answer to this question is no, repeat the balance procedure.

Instructor's Response ______________________________
____
____

Name ______________________________ Date ____________________

On-Car Wheel Balancing

Upon completion of this job sheet, you should be able to perform on-car wheel balancing procedures.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task F-6: Dismount, inspect, and remount tire on wheel. Balance wheel and tire assembly (static and dynamic).

Tools and Materials

On-car wheel balancer
Car
Wheel weights

Describe the Vehicle Being Worked On:

Year __________ Make ______________ Model ____________________
VIN __________________________ Engine type and size ________________

Procedure — Task Completed

1. Wash mud and debris from the wheel and tire. ☐
2. Raise the wheel being balanced 5 in. (12 cm) off the floor; be sure the chassis is securely supported on safety stands. ☐
3. Remove stones and other objects from the tire tread.
   Are all objects removed from the tire tread? ☐ Yes ☐ No
   Instructor check ________________________________
4. Inspect the tire tread and sidewall condition.
   Tread and sidewall condition ____________________________
   ____
   Types of tire tread wear ________________________________
   ____
   Causes of tire tread wear ________________________________
   ____
   Based on your inspection of the tire tread and sidewall, state the necessary tire service.
   ____
   ____
5. Check the wheel bearing adjustment and adjust to specifications if necessary.
   Wheel bearing adjustment: ☐ Satisfactory ☐ Unsatisfactory

CAUTION: Do not spin the front wheels on a front-wheel-drive vehicle with the floor jack under the chassis and the suspension dropped downward. Under this condition, severe angles exist in the front drive axle joints, and these joints may be damaged if the wheels are rotated with the balancer. Place the floor jack under the lower control arm to raise the wheel.

CAUTION: To obtain proper wheel balance, spin the wheel only to the speed where the vibration occurs. Do not spin the wheel at excessive speeds.

6. Install the electronic vibration sensor between the lower control arm and the floor.

   Is the vibration sensor properly installed? ☐ Yes ☐ No

   Instructor check ______________________________

7. Chalk mark a reference mark on the outer sidewall of the tire.

8. Spin the wheel just fast enough to produce vibration on the front bumper.

9. When vibration causes strobe light flashing, move the balancer drum away from the tire and allow the tire to spin freely.

10. Shine the strobe light around the tire sidewall and note the chalk-mark position.
    Chalk-mark clock position ______________________________

11. Note the pointer position on the meter.

    Meter pointer position ______________________________

12. Use the balancer's brake plate to slow and stop the wheel.

13. Rotate the wheel until the chalk mark is in the exact position where it appeared under the strobe light. The heavy spot is now at the bottom of the wheel and the balancing weight should be attached 180° from the heavy spot. Install the amount of weight indicated on the meter.

    Amount of wheel weight installed ______________________________

14. Spin the wheel again. If the wheel balance is satisfactory, the meter pointer will read in the balanced position. If the pointer does not indicate a balanced wheel, shine the strobe light on the tire sidewall. If the installed wheel weight is at the 12 o'clock position, additional weight is required. A 6 o'clock weight position indicates excessive weight. A 3 o'clock or 9 o'clock weight position may be corrected by moving the weight 1 in. (2.5 cm) toward the 12 o'clock position.

    Tire and Wheel balance: ☐ Satisfactory ☐ Unsatisfactory

    If the wheel balance is unsatisfactory, state the action required to balance tire and wheel.

    ____

    ____

Instructor's Response ______________________________

____

____

Name ______________________________ Date ____________________

Diagnose Tire and Wheel Vibration, Steering Pull, and Chassis Waddle

Upon completion of this job sheet, you should be able to diagnose tire and wheel vibration problems, steering pull, and chassis waddle.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task F-2: Diagnose wheel/tire vibration, shimmy, and noise, determine necessary action.

Tools and Materials

Late model vehicle

Describe the Vehicle Being Worked On:

Year __________ Make _______________ Model __________________________

VIN __________________________ Engine type and size ____________________

Procedure

1. Drive the vehicle at 10 mph (16 kmh), 20 mph (32 kmh), 30 mph (48 kmh), 40 mph (64 kmh), 50 mph (80 kmh), 60 mph (96.5 kmh). Maintain each vehicle speed long enough to diagnose tire, steering, and chassis problems. Do not exceed the legal speed limit. Did the vehicle indicate any of the following problems at these various speeds?
2. Chassis waddle. Speed at which waddle occurred ____________________.

   Did the waddle occur at the front or the rear of the vehicle? __________________

   List the possible causes of waddle and the neccessary diagnostic steps and service procedures to correct the problem.

   ____

   ____

   ____
3. Tire thump and vibration. Speed at which tire thump or vibration occurred ____________________. At which corner of the vehicle did the thump and vibration occur. ____________________

   List the possible causes of tire thump and vibration and the necessary diagnostic steps and service procedures to correct the problem.

   ____

   ____

   ____
4. Wheel shimmy. Speed at which wheel shimmy occurred. ____________________

List the possible cause of wheel shimmy, and the necessary diagnostic steps and service procedures to correct the problem.

____

____

____

5. Steering pull. Speed at which steering pull occurred. ________________
Direction of steering pull. ________________
List the possible causes of steering pull, and the necessary diagnostic steps and service procedures to correct the problem.

____

____

____

Instructor's Response ____

____

____

Name ______________________ Date ______________

Inspect, Diagnose, and Calibrate Tire Pressure Monitoring Systems

Upon completion of this job, you should be able to inspect, diagnose, and calibrate tire pressure monitoring systems (TPMSs).

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task F-11: Inspect, diagnose, and calibrate TPMSs.

Tools and Materials

Late model vehicle

Scan tool

Describe the vehicle being worked on:

Year ________ Make ____________ Model ________________

VIN ________________ Engine type and size ____________

Procedure

1. Connect a scan tool to the data link connector (DLC) under the left side of the instrument panel, and turn the scan tool on.
2. Turn the ignition switch on, and do not start the engine.
3. Select antenna module on the scan tool. Check for the DTCs related to the antenna module. If there are DTCs displayed with a "U" prefix, there is a defect in the data link communications. If the scan tool cannot communicate with the antenna module, or there are DTCs related to this module or the data link communications, proceed with further diagnosis of these items.
4. Check for DTCs related to the radio/audio system. The antenna grid in the rear window receives TPMS sensor signals. This grid shares its connector with the AM/FM antenna grid. If any radio/audio system DTCs are present, proceed with the diagnosis of the radio/audio system.
5. Check for keyless entry system DTCs displayed in the scan tool. The antenna module also controls the keyless entry system. If the scan tool displays DTCs related to the keyless entry system, proceed with the diagnosis of these DTCs.
6. Check for TPMS DTCs on the scan tool display. If TPMS DTCs are present, diagnose the cause of these DTCs.

   List and interpret the DTCs displayed on the scan tool ______________________

   ____

   ____

TPMS Learning Procedure

1. Connect a scan tool to the DLC.
2. Turn on the ignition switch, and do not start the engine.
3. Apply the parking brake.
4. Select Special Functions on the scan tool.
5. Select Sensor Learn Mode on the scan tool, and press the Enter key.
6. Press the On soft key. A horn chirp should sound to indicate the sensor learn mode is enabled.
7. Starting with the LF tire, increase or decrease the tire pressure for 5–8 seconds or until a horn chirp sounds. The horn chirp may occur before the 5- to 8-second time period, or up to 30 seconds after this time period.

WARNING: If you are increasing tire pressure during the learning procedure, never inflate a tire above the vehicle manufacturer's maximum specified tire pressure. This action may cause personal injury and tire damage.

8. After the horn chirp sounds, repeat step 7 on the other 3 or 4 sensors in the following order:
   (a) RF
   (b) RR
   (c) LR
   (d) Spare tire (if applicable)

If a horn chirp is not heard after 35 seconds for any of the 4 sensors, turn off the ignition switch and exit the learn mode on the scan tool. Repeat the sensor learning procedure from step 4.

9. After the learning procedure has been completed on all the sensors, a double horn chirp sounds to indicate the learning procedure is completed on all the sensors.
10. Turn off the ignition switch and disconnect the scan tool.
11. Inflate all the tires to the specified pressure.

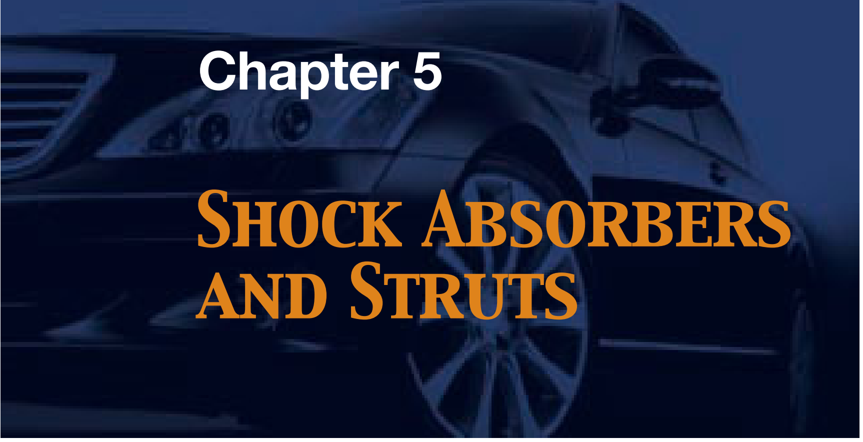
    Learning procedure completed Yes ____________ No ____________. If the answer is no, state the reason for the test not being completed ________________________________

    ____

    Instructor's Response ____

    ____

    ____



Chapter 5

Shock Absorbers and Struts

Upon completion and review of this chapter, you should be able to understand and describe:

- The three purposes of shock absorbers.
- How shock absorbers contribute to vehicle safety.
- Wheel jounce and rebound.
- Spring operation during wheel jounce and rebound.
- Shock absorber operation during wheel jounce.
- Shock absorber operation during wheel rebound.
- The advantages of nitrogen-gas-filled shock absorbers and struts.
- Shock absorber ratios.
- Travel-sensitive shock absorber operation.
- The operation of an adjustable shock absorber.
- The operation of load-leveling struts and shock absorbers.

Introduction

Two front **shock absorbers** are connected from the front suspension to the chassis, and two rear shock absorbers are attached between the rear suspension and the chassis. Shock absorbers have three main purposes:

1. They control spring action and oscillations to provide the desired ride quality.
2. They help prevent body sway and lean while cornering.
3. They reduce the tendency of a tire tread to lift off the road, which improves tire life, traction, and directional stability.

Shock absorbers are devices used to control, or dampen, spring oscillations.

Because shock absorbers control spring action, spring oscillations, and chassis oscillations, they contribute to vehicle safety and passenger comfort. If the shock absorbers are worn out, excessive chassis oscillations may occur, particularly on rough road surfaces. These excessive chassis oscillations may result in loss of steering control. Worn-out shock absorbers also cause excessive body lean and sway while cornering, which may cause the driver to lose control of the vehicle. Shock absorbers are extremely important to providing longer tire life and improving vehicle handling, steering quality, and ride quality.

Shock absorber design is matched to the deflection rate of the coil spring to control the spring action. Several different types of shock absorbers are available for special service requirements.

Shock Absorber Design

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The lower half of a shock absorber is a twin tube steel unit filled with hydraulic oil and nitrogen gas (Figure 5-1). In some shock absorbers, the nitrogen gas is omitted. A relief valve is located in the bottom of the unit, and a circular lower mounting is attached to the lower tube. This mounting contains a rubber isolating bushing, or grommet. A piston and rod assembly is connected to

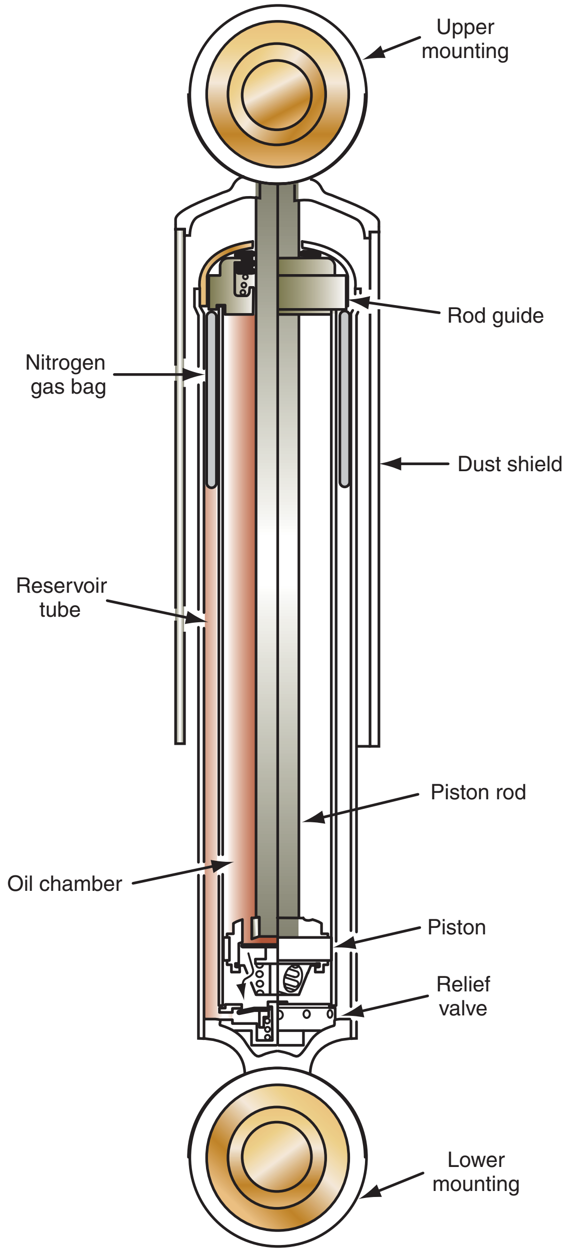

FIGURE 5-1 **Shock absorber filled with hydraulic oil and nitrogen gas.**

the upper half of the shock absorber. This upper portion of the shock absorber has a dust shield that surrounds the lower twin tube unit. The piston is precision fit in the inner cylinder of the lower unit. A piston rod guide and seal are located in the top of the lower unit. A circular upper mounting with a rubber bushing is attached to the top of the shock absorber.

Shock Absorber Operation

Shock absorbers are usually mounted between the lower control arms and the chassis. When a vehicle wheel strikes a bump, the wheel and suspension move upward in relation to the chassis. Upward wheel movement is referred to as **jounce travel.** This jounce action causes the spring to deflect or compress. Under this condition, the spring stores energy and springs back downward with all the energy absorbed when it deflected upward. This downward spring and wheel action is called **rebound travel.** If this spring action were not controlled, the wheel would strike the road with a strong downward force, and the wheel jounce would occur again. Therefore, some device must be installed to control the spring action, or the wheel

would bounce up and down many times after it hit a bump, causing passenger discomfort, directional instability, and suspension component wear.

Shock absorbers are installed on suspension systems to control spring action. When a wheel strikes a bump and jounce travel occurs, the shock absorber lower tube unit is forced upward. This action forces the piston downward in the lower tube unit. Since oil cannot leak past the piston, the oil in the lower unit is forced through the piston orifices or valves to the upper oil chamber. These valves provide precise oil flow control and control the upward action of the wheel and suspension, which is referred to as a shock absorber compression stroke (Figure 5-2).

When the spring expands downward in rebound travel, the lower shock absorber unit is also forced downward. When this occurs, the piston moves upward in the lower tube unit, and hydraulic oil is forced through the piston orifices or valves from the upper oil chamber to the lower oil chamber. Since the valves restrict oil flow with precise control, the downward suspension and wheel movement is controlled.

When the shock absorber piston moves, oil is forced through the piston. Since the piston valves and orifices resist the flow of oil, friction and heat are created. The resistance of the oil moving through the piston must be calibrated as closely as possible to the spring's deflection rate or strength. Wheels and suspension systems deflect at many different speeds, depending on the type and size of bump and the vehicle speed. The resistance of a shock absorber piston increases with the square of its speed. For example, if the wheel deflection speed increases four times, the piston resistance is sixteen times as great. Therefore, if a wheel strikes a large bump at high speed, the wheel deflection and rebound can be effectively locked by the shock absorber. Shock absorber engineers prevent this action by precisely designing shock absorber

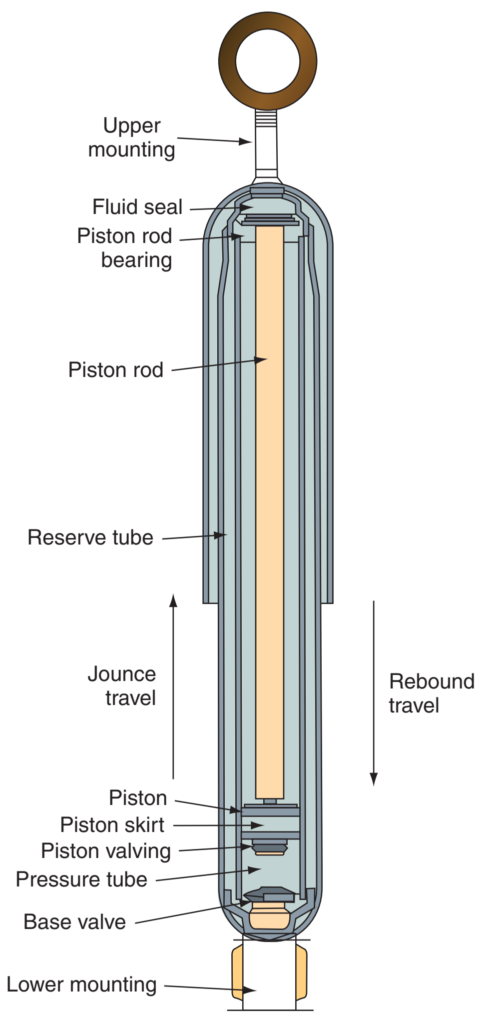

FIGURE 5-2 **Shock absorber action.**

valves and orifices to provide enough friction to prevent the spring from overextending on the rebound stroke. These piston valves and orifices must not create excessive friction, which slows the wheel from returning to its original position.

Shock absorber pistons have many different types of valves and orifices. In some pistons, small orifices control the oil flow during slow wheel and suspension movements. Stacked steel valves control the oil flow during medium speed wheel and suspension movements. During maximum wheel and suspension movements, larger orifices between the piston valves provide oil flow control. On other shock absorber pistons, the stacked steel valves alone provide oil flow control. Regardless of the piston orifice and valve design, the shock absorber must be precisely matched to absorb the spring's energy.

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During fast upward wheel movement on the compression stroke, excessive pressure in the lower oil chamber forces the base valve open and thus allows oil to flow through this valve to the reservoir. The nitrogen gas provides a compensating space for the oil that is displaced into the reservoir on the compression stroke and when the oil is heated. Since the gas exerts pressure on the oil, cavitation, or foaming of the oil, is eliminated. When oil bubbles are eliminated in this way, the shock absorber provides continuous damping for wheel deflections as small as 0.078 in (2.0 mm). A rebound rubber is located on top of the piston. If the wheel drops downward into a hole, the shock absorber may become fully extended. Under this condition, the rebound rubber provides a cushioning action.

AUTHOR'S NOTE: Of all the suspension components, shock absorbers and struts contribute the most to ride quality. As the vehicle is driven over road irregularities, the shock absorbers or struts are continually operating to control the spring action and provide acceptable ride quality. It has been my experience that shock absorbers and struts usually wear out first in suspension systems, because they are working every time a wheel strikes a road irregularity. Therefore, you must understand not only shock absorber and strut operation but also how ride quality is affected if these components are not functioning properly. Thus, you must know shock absorber and strut diagnosis and service procedures.

Gas-Filled Shock Absorbers and Struts

A **gas-filled shock absorber** contains a nitrogen gas charge to maintain pressure on the oil in the shock.

Gas-filled units are identified with a warning label. If a **gas-filled shock absorber** is removed and compressed to its shortest length, it should re-extend when it is released. Failure to re-extend indicates that shock absorber or strut replacement is necessary.

CAUTION:
When drilling worn-out shock absorbers or struts to relieve the gas pressure prior to disposal, drill the shock absorber only at the vehicle manufacturer's specified location.

WARNING: New gas-filled shock absorbers are wired in the compressed position for shipping purposes. Exercise caution when cutting this wire strap because shock absorber extension may cause personal injury. After the upper shock absorber attaching bolt is installed, the wire strap can be cut to allow the unit to extend. Front gas-filled struts have an internal catch that holds them in the compressed position. This catch is released when the strut rod is held and the strut rotated 45° counterclockwise.

WARNING: Do not throw gas-filled shock absorbers or struts in the fire or apply excessive heat or flame to these units. These procedures may cause the unit to explode, resulting in personal injury.

WARNING: Never apply heat to a shock absorber or strut chamber with an acetylene torch. This action may cause a shock absorber or strut explosion resulting in personal injury.

Heavy-Duty Shock Absorber Design

Some **heavy-duty shock absorbers** have a dividing piston in the lower oil chamber. The area below this piston is pressurized with nitrogen gas to 360 pounds per square inch (psi), or 2,482 kilopascals (kPa). Hydraulic oil is contained in the oil chamber above the dividing piston. The other main features of the heavy-duty shock absorber are:

1. High-quality seal for longer life.
2. Single tube design to prevent excessive heat buildup. This design may be called a Mono-tube shock absorber.
3. Rising rate valve to provide precise spring control under all conditions.

The operation of the heavy-duty shock absorber is similar to that of the conventional type (Figure 5-3). A dent in the oil chamber will affect shock absorber operation on this type of design.

Heavy-duty shock absorbers have several design features that provide improved durability compared with conventional shock absorbers.

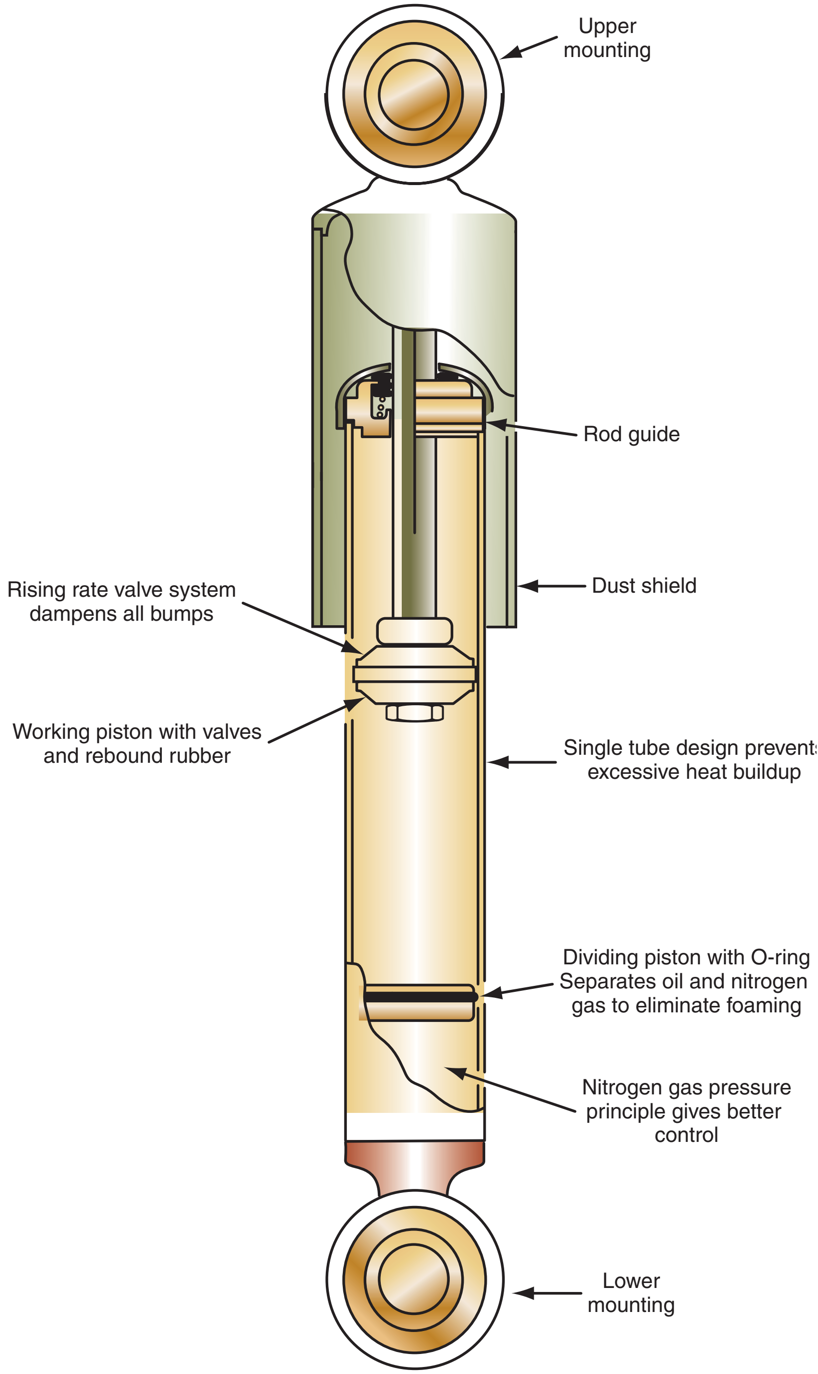

FIGURE 5-3 **Heavy-duty shock absorber.**

Shock Absorber Ratios

Most automotive shock absorbers are a double-acting-type that controls spring action during jounce and rebound wheel movements. The piston and valves in many shock absorbers are designed to provide more extension control than compression control. An average shock absorber may have 70 percent of the total control on the extension cycle, and thus 30 percent of the total control is on the compression cycle. Shock absorbers usually have this type of design because they must control the heavier sprung body weight on the extension cycle. The lighter unsprung axle, wheel, and tire weight are controlled by the shock absorber on the compression cycle. A shock absorber with this type of design is referred to as a 70/30 type. **Shock absorber ratios** vary from 50/50 to 80/20.

Shock absorber ratios indicate the amount of control on the extension and compression cycles.

A shock absorber is mounted between the rear axle and the chassis on a front-wheel-drive car (Figure 5-4). Mounting bolts extend through hangers on the rear axle and chassis. These bolts also pass through the isolating bushings on each of the shock absorbers. The isolating bushings are very important for preventing vibration and noise. Front shock absorbers may be mounted in a similar way between the lower control arms and the chassis.

Strut Design, Front Suspension

A strut-type front suspension is used on most front-wheel-drive cars and some rear-wheel-drive cars. Internal strut design is very similar to shock absorber design, and **struts** perform the same functions as shock absorbers. Some struts have a replaceable cartridge. In many strut-type suspension systems, the coil spring is mounted on the strut. The coil spring is largely responsible for proper curb riding height. A weak or broken coil spring reduces curb riding height and provides harsh riding. The lower end of the front suspension strut is bolted to the steering knuckle (Figure 5-5).

Struts are similar to shock absorbers, but struts are usually positioned between the knuckle and the chassis to provide knuckle support.

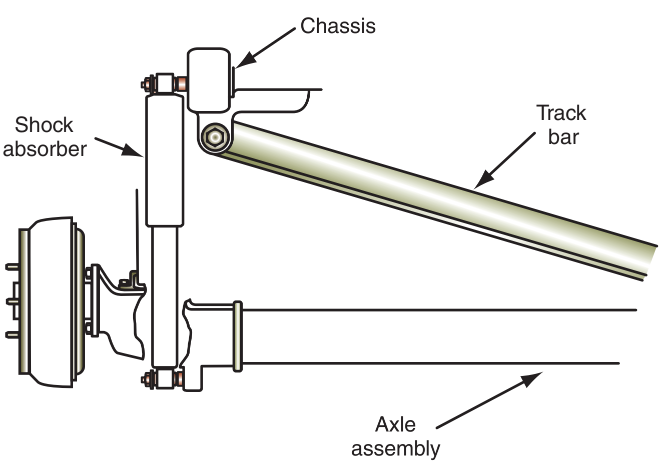

FIGURE 5-4 **Rear shock absorber mounting on a front-wheel-drive car.**

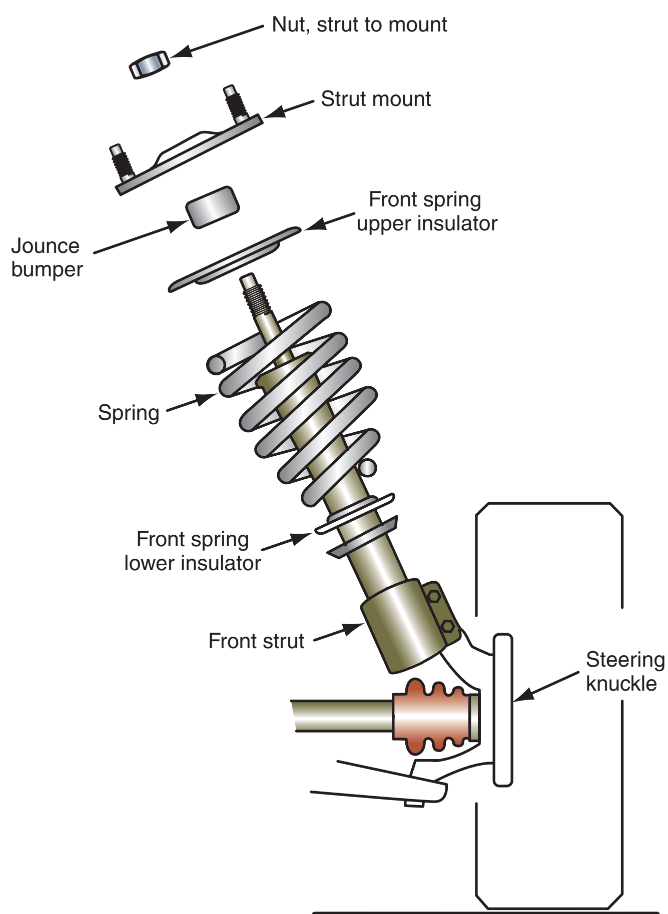

FIGURE 5-5 **Front strut assembly.**

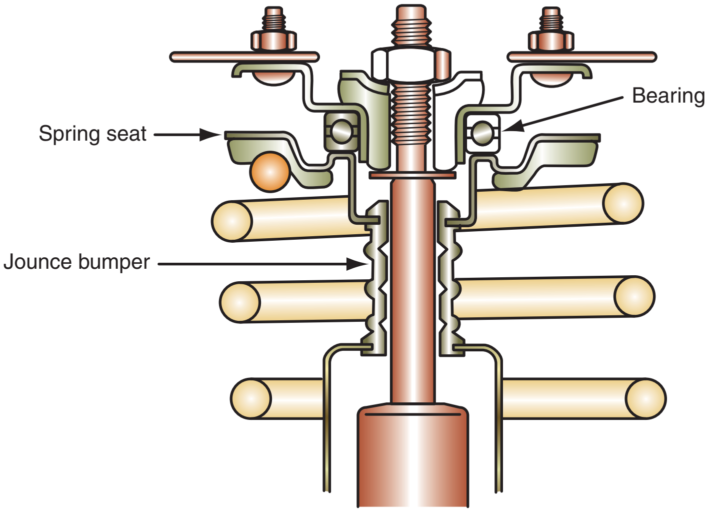

FIGURE 5-6 **Upper strut mount.**

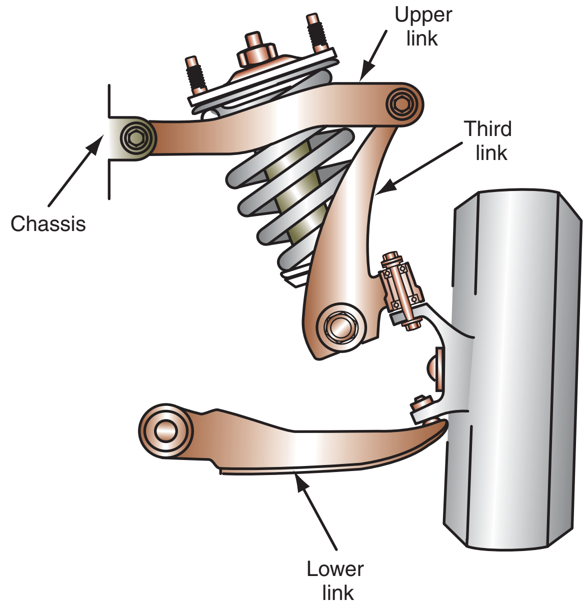

FIGURE 5-7 **Multilink front suspension with strut connected between the upper link and the strut tower.**

An **upper strut mount** is attached to the strut, and this mount is bolted into the chassis strut tower. A lower spring seat is part of the strut assembly, and a lower insulator is positioned between the coil spring and the spring seat on the strut. Another **spring insulator** is located between the coil spring and the upper strut mount. The two insulators prevent metal-to-metal contact between the spring and the strut, or mount. These insulators reduce the transmission of noise and harshness from the suspension to the chassis. A rubber spring bumper is positioned around the strut piston rod. When a front wheel strikes a large road irregularity and the strut is fully compressed, the jounce bumper provides a cushioning action between the top of the strut and the upper support. The jounce bumper stops the upward wheel and suspension movement before the spring is completely compressed. If the spring becomes completely compressed and the coils strike each other, ride quality is very harsh. Therefore, the jounce bumper in the strut improves ride quality. Most jounce bumpers are made from butyl rubber. Some late model vehicles have microcellular urethane (MCU) jounce bumpers, which are lighter than rubber and provide more progressive cushioning to improve ride quality. MCU jounce bumpers are also 20 to 40 percent lighter than rubber jounce bumpers, which reduces road noise transmission to the passenger compartment. In relation to temperature changes, MCU jounce bumpers remain more stable and provide improved ride quality regardless of the temperature. The upper strut mount contains a bearing, upper spring seat, and jounce bumper (Figure 5-6).

When the front wheels are turned, the front strut and coil spring rotate with the steering knuckle. The strut-and-spring assembly rotates on the upper strut mount bearing.

Some cars have a multilink front suspension with an upper link connected from the chassis to the steering knuckle. The strut is connected from the upper link to the strut tower (Figure 5-7). A bearing is mounted between the upper link and the steering knuckle, and the wheel and knuckle turn on this bearing and the lower ball joint. Therefore, the coil spring and strut do not turn when the front wheels are turned, and a bearing in the upper strut mount is not required (Figure 5-8).

A Bit of History

For many years, rear-wheel-drive cars were equipped with front and rear shock absorbers. Most front-wheel-drive cars are equipped with front struts, and some of these cars also have rear struts. Since massive numbers of front-wheel-drive cars have been introduced in the 1980s and 1990s, front and rear struts are now very common.

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Shock Absorber and Strut Design, Rear Suspension

In some rear suspension systems, the lower end of the strut is bolted to the spindle, and the top of the strut is connected through a strut mount to the chassis. The rear coil springs are mounted separately from the struts. These springs are mounted between the lower control arms and the chassis (Figure 5-9).

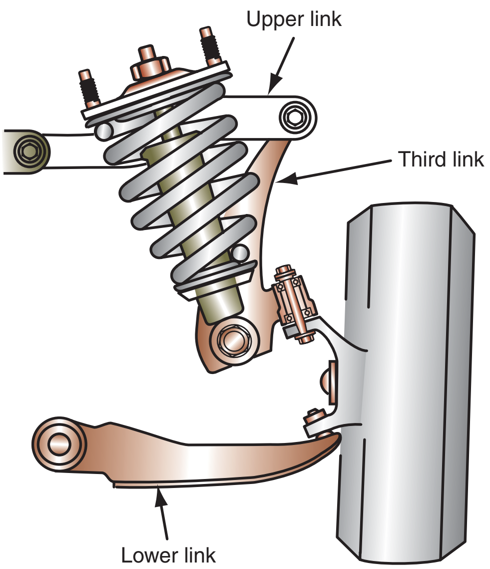

FIGURE 5-8 **Multilink front suspension with knuckle and wheel pivots at the upper link bearing and lower ball joint, and a non-rotating upper strut mount.**

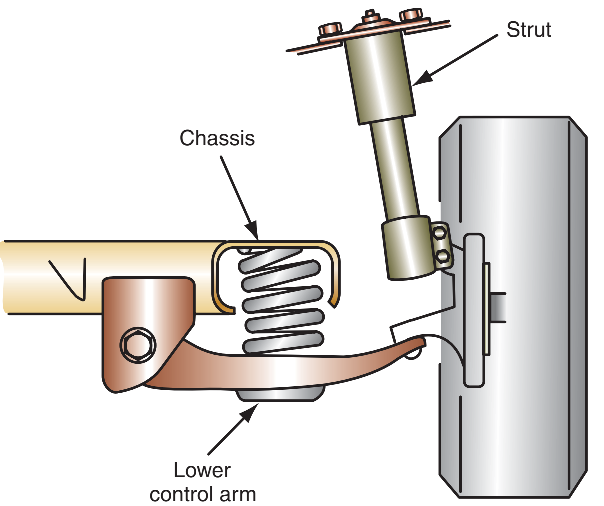

FIGURE 5-9 **Rear suspension system with coil springs mounted separately from the struts.**

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In other rear suspension systems, the coil springs are mounted on the rear struts (Figure 5-10). An upper insulator is positioned between the top of the spring and the upper spring support, and a lower insulator is located between the bottom of the spring and the spring mount on the strut. A rubber spring bumper is positioned on the strut piston rod. If a rear wheel strikes a severe road irregularity and the strut is fully compressed, the spring bumper provides a cushioning action between the top of the strut and the upper support.

On some rear-wheel-drive light-duty trucks and sport utility vehicles (SUVs), the rear shock absorbers are slanted rearward and inward (Figure 5-11). On other light-duty trucks

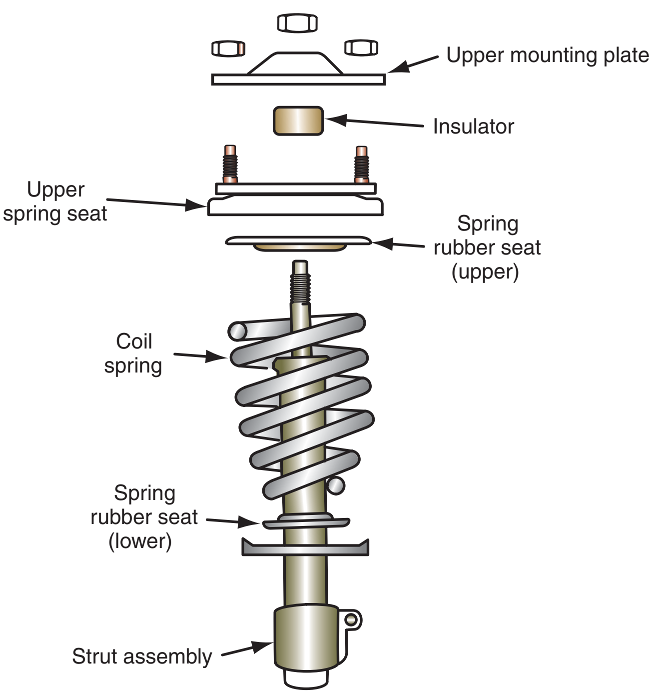

FIGURE 5-10 **Rear suspension system with coil springs mounted on the struts.**

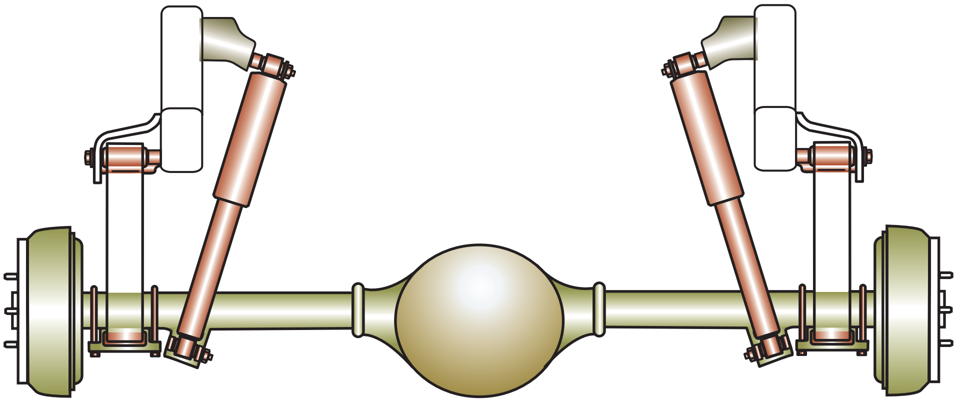

FIGURE 5-11 **Rear shock absorber mounting, sport utility vehicle (SUV).**

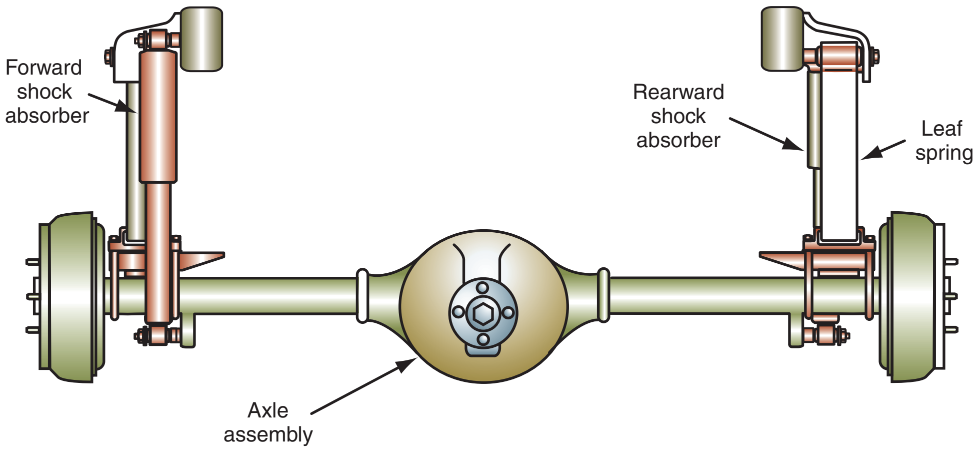

FIGURE 5-12 **Shock absorbers staggered on each side of the rear axle.**

and SUVs, the rear shock absorbers are staggered on each side of the rear axle (Figure 5-12). Either of these shock absorber mountings improves ride quality and reduces noise, vibration, and harshness (NVH).

Travel-Sensitive Strut

Some **travel-sensitive struts** contain narrow longitudinal grooves in the lower oil chamber (Figure 5-13). These grooves are parallel to the piston orifices, and some oil flows through the grooves as well as the orifices. Under normal driving and road conditions, the orifices and grooves are calibrated to provide normal spring damping and control. If the front wheel drops suddenly, such as when it strikes a large hole, the piston moves into the narrow portion of the oil chamber. Under this condition, all the oil must flow through the piston orifices, which greatly increases the strut's resistance to movement and the suspension damping action. This strut action prevents harsh impacts against the internal strut rebound rubber.

Travel-sensitive struts vary the amount of strut control in relation to strut travel.

Adjustable Struts

Some **adjustable struts** have a manual adjustment that allows the vehicle owner or technician to adjust the struts to suit driving conditions (Figure 5-14). The strut adjusting knob varies the strut orifice opening. This knob has eight possible settings. The factory

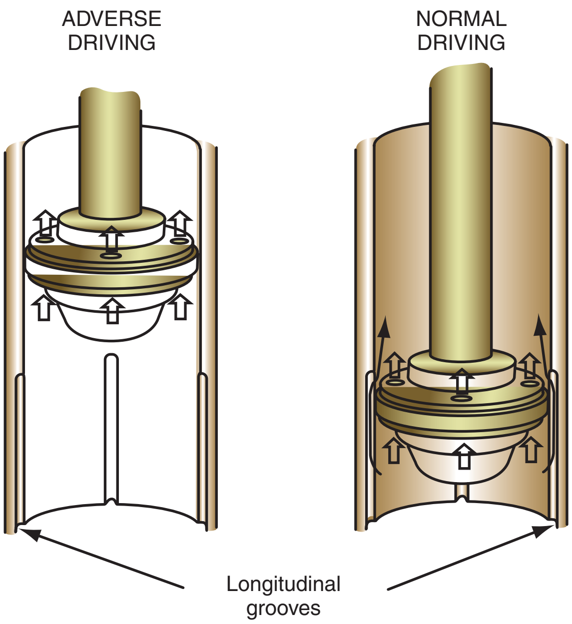

FIGURE 5-13 **Travel-sensitive strut.**

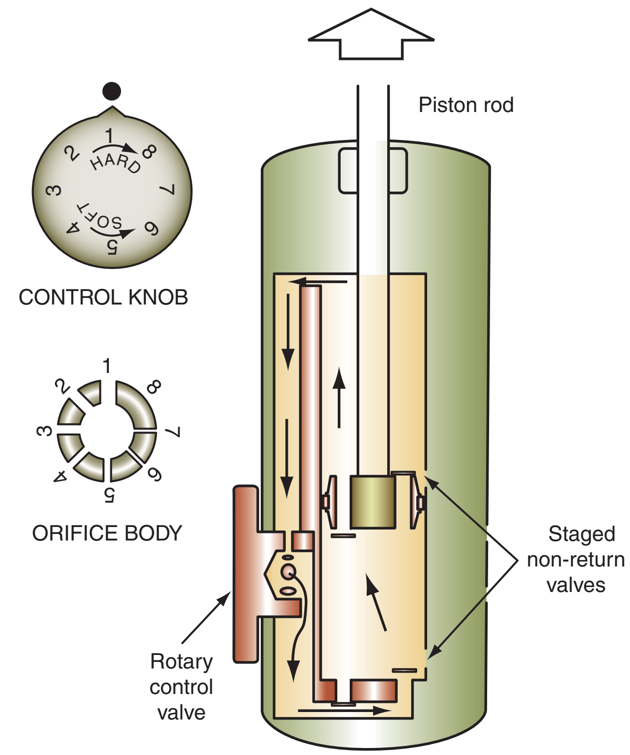

FIGURE 5-14 **Manual Adjustable strut.**

setting is No. 3, which provides average suspension control. The No. 1 setting provides reduced spring control and the softest ride, whereas a No. 8 adjustment gives increased spring control and the hardest ride. The adjustment knob is usually accessible without raising the vehicle.

Load-Leveling Shock Absorbers

Load-leveling rear shock absorbers or struts are used with an electronic height control system. An onboard air compressor pumps air into the rear shocks to raise the rear of the vehicle, and an electric solenoid releases air from the shocks to lower the rear chassis. An electromagnetic height sensor may be contained in the shock absorber, or an external sensor may be used (Figure 5-15). This sensor sends a signal to an electronic control module in relation to the rear suspension height. The module controls the air compressor and the exhaust solenoid to control air pressure in the shock absorbers. This action maintains a specific rear suspension trim height regardless of the load on the rear suspension. If a heavy package is placed in the trunk, the vehicle chassis is forced downward. However, the **load-leveling shock absorbers** extend to restore the original rear suspension height.

Load-leveling shock absorbers use air pressure supplied to the shock absorbers to maintain rear suspension height. Load-leveling shock absorbers may be called air shocks.

Aftermarket air shock absorbers are available. These shock absorbers contain an air valve connection. A shop air hose may be used to supply the desired pressure in these air shock absorbers.

Aftermarket spring-assisted shock absorbers are also available. These are conventional shock absorbers with a small coil spring mounted over them. Upper and lower spring seats are attached near the top and bottom of these shock absorbers to support and retain the spring. The coil springs on the shock absorbers help the springs in the suspension system support the vehicle weight.

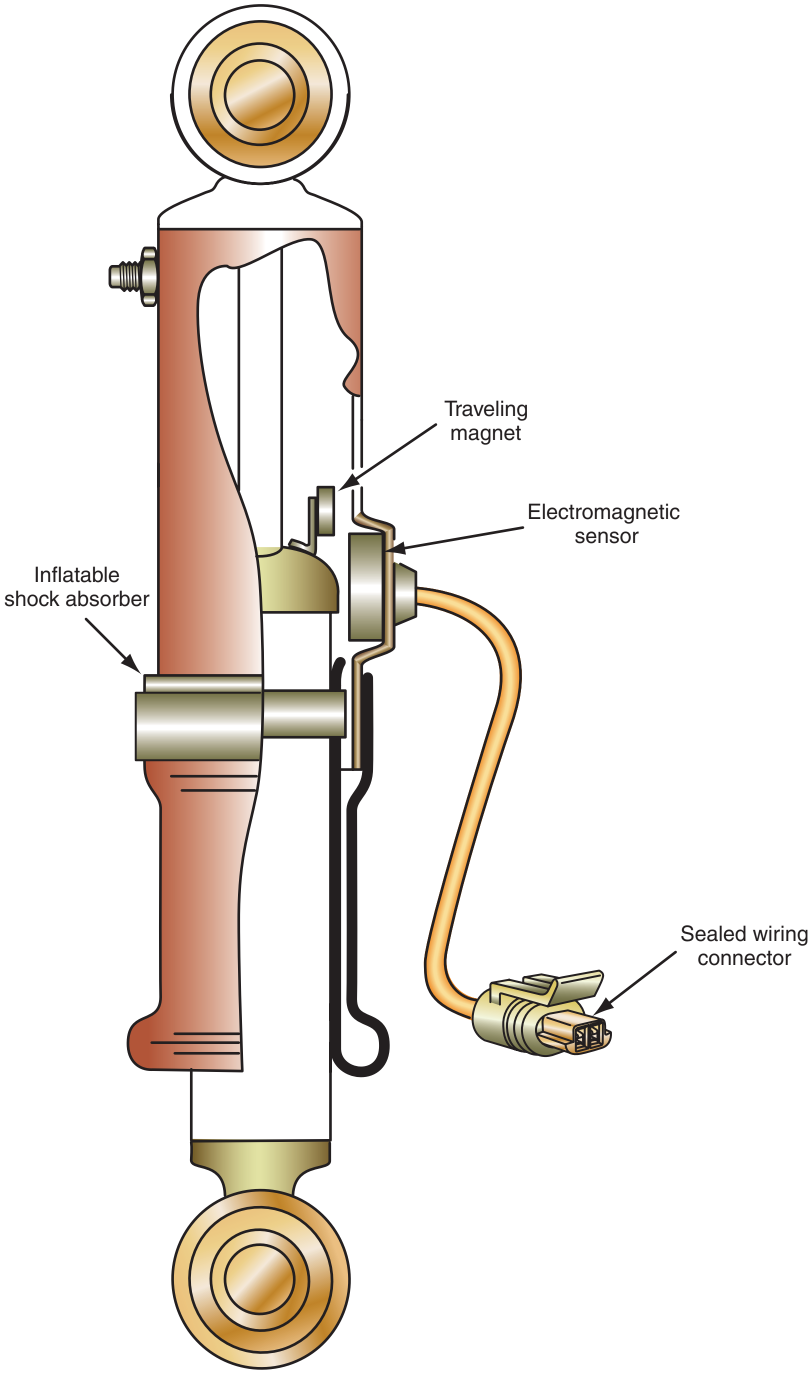

FIGURE 5-15 **Load-leveling strut.**

Electronically Controlled Shock Absorbers and Struts

Many cars equipped with computer-controlled **active suspension systems.** In these systems, a computer-controlled actuator is positioned in the top of each shock absorber or strut (Figure 5-16). The shock absorber or strut actuators rotate a shaft inside the piston rod, and this shaft is connected to the shock valve. Many of these systems have two modes, soft and firm. In the soft mode, the actuators position the shock absorber valves so there is less restriction to the movement of oil. When the computer changes the actuators to the firm mode, the actuators position the shock valves so they provide more restriction to oil movement, which provides a firmer ride.

Computer-controlled suspension systems may be referred to as **active suspension systems**.

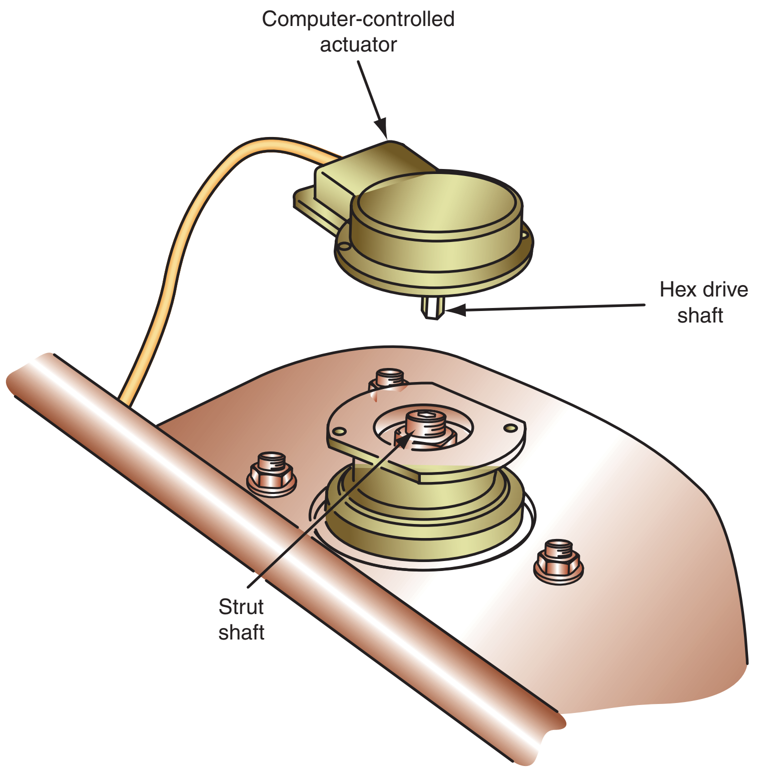

FIGURE 5-16 **Computer-controlled strut actuator.**

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Some electronically controlled shock absorbers and struts contain a synthetic **magneto-rheological fluid** that contains numerous small, suspended metal particles. Each shock absorber contains a winding that is energized by the suspension computer. If the shock absorber winding is not energized, the metal particles in the fluid align randomly in the fluid. Under this condition, the fluid has a mineral oil-like consistency and the fluid moves easily through the shock absorber orifices. If the suspension computer energizes a shock absorber winding, the metal particles in the fluid are aligned into fibrous structures. When this occurs, the fluid has a jelly-like consistency for a firm ride (Figure 5-17). The computer can change the shock absorber damping characteristics in 1 millisecond (ms) and can also supply a varying amount of current through the shock absorber windings to provide a wide variety of shock absorber damping characteristics.

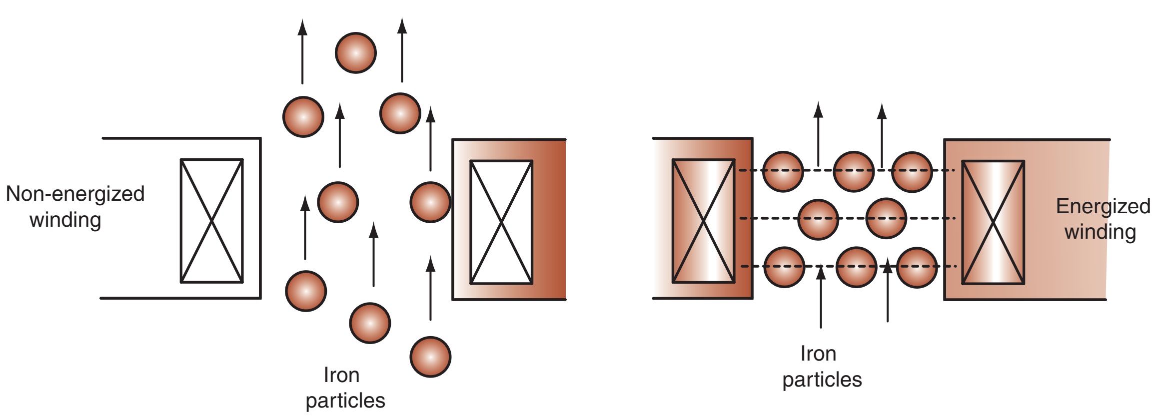


FIGURE 5-17 **Magneto-rheological fluid action in a strut or shock absorber.**

Summary

- Shock absorbers or struts play a very important role in ride quality, steering control, and tire life.
- Tire and wheel jounce travel occurs when a tire strikes a bump in the road surface and the tire and wheel move upward.
- Rebound tire and wheel travel occurs when the tire and wheel move downward after jounce travel.
- When a spring is deflected upward during jounce travel, it stores energy. The spring then expands downward in rebound travel with all the energy it stored during the jounce travel. If the spring action is not controlled, the energy in the spring during rebound travel drives the tire against the road surface with excessive force. This action drives the tire and wheel back upward in jounce travel and the wheel continues oscillating up and down.
- The shock absorbers control spring action and prevent excessive tire and wheel oscillations.
- During jounce travel, the piston moves downward in the lower shock absorber chamber; during rebound travel, this piston moves upward. Because the lower shock absorber chamber is sealed and filled with oil, this oil must flow past the piston during any piston movement.
- Valves and openings in the shock absorber piston provide precision control of the oil flow past the piston to control spring action. Shock absorber valves are matched to the amount of energy that may be stored in the spring.
- A nitrogen gas charge is located in the oil reservoir of many shock absorbers and struts to prevent oil cavitation or foaming, which provides more positive shock absorber action.
- Shock absorber ratio refers to the difference between the shock absorber control on the compression and extension cycle. Many shock absorbers provide more control on the extension cycle.
- Internal design is similar in shock absorbers and struts, but struts also support the coil spring.
- Most front struts are connected between the steering knuckle and the upper strut mount.
- Many rear struts are connected between the spindle and the upper support.
- A travel-sensitive shock absorber provides increased resistance to piston movement as the shock absorber is extended.
- Adjustable shock absorbers and struts have a manual adjustment that allows the technician or owner to adjust the strut orifice opening.
- Load-leveling shock absorbers have air pumped into the shock absorbers from an onboard compressor to maintain a specific rear suspension height regardless of the rear suspension load.
- Most front struts rotate on the upper strut mount bearing as the front wheels are turned.

Terms to Know

Active suspension systems
Adjustable struts
Gas-filled shock absorber
Heavy-duty shock absorbers
Jounce travel
Load-leveling shock absorbers
Magneto-rheological fluid
Rebound travel
Shock absorbers
Shock absorber ratios
Spring insulator
Struts
Travel-sensitive struts
Upper strut mount

Review Questions

Short Answer Essays

1. Describe spring action during jounce and rebound travel.
2. Describe uncontrolled spring action without a shock absorber.
3. Explain shock absorber operation.
4. Describe the vehicle safety hazards created by worn-out shock absorbers.
5. Explain shock absorber ratio.
6. Explain the purpose of the nitrogen gas charge in shock absorbers and struts.

7. Explain the differences between heavy-duty and conventional shock absorbers.
8. Identify the purposes of an upper strut mount.
9. Explain the purpose of strut and spring insulators.
10. Describe the purpose of the rubber spring bumper on a strut piston rod.

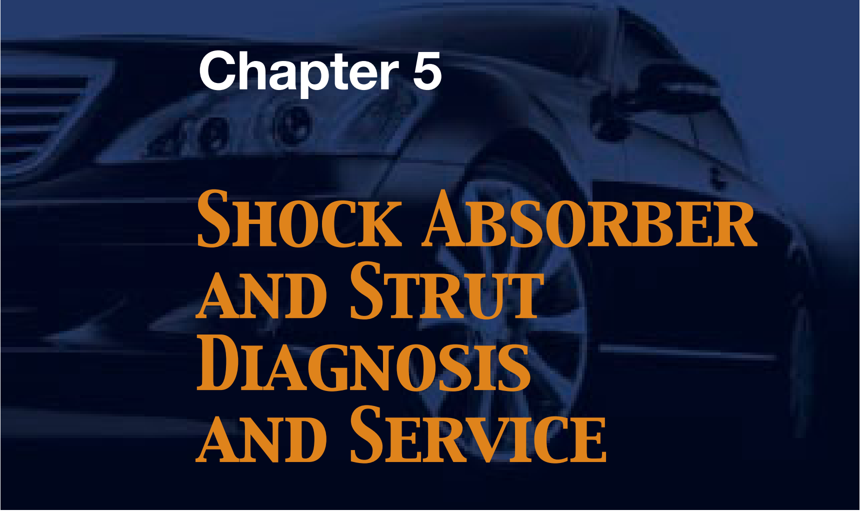
Fill-in-the-Blanks

1. Shock absorbers control spring action and prevent excessive spring _______________.
2. Shock absorber design is matched to the _______________ rate of the spring.
3. The valves in most shock absorbers are designed to vary the oil flow through the valve in relation to the amount of _______________ movement.
4. The nitrogen gas charge in a shock absorber prevents oil _______________ and _______________.
5. The single tube design in a heavy-duty shock absorber prevents excessive _______________ _______________.
6. A shock absorber with a 70/30 ratio provides more control on the _______________ cycle.
7. The lower end of many front struts is bolted to the steering _______________ .
8. When a higher number is selected on the adjustment knob of an adjustable strut, the strut provides a _______________ ride.
9. Load-leveling shock absorbers may have an internal _______________ _______________.
10. Travel-sensitive shock absorbers provide increased spring control when the shock absorber is_______________ .

Multiple Choice

1. The main purpose of shock absorbers and struts is to:
   A. Control spring action.
   B. Prevent fore-and-aft wheel movement.
   C. Reduce lateral wheel movement.
   D. Prevent wheel shimmy.
2. All of these statements about shock absorber design and operation are true EXCEPT:
   A. The oil flow through the orifices and valves is matched to the spring's strength and deflection rate.
   B. A typical shock absorber may have 70 percent of the total control on the extension cycle.
   C. During jounce wheel travel the piston moves upward in the shock absorber lower tube unit.
   D. A nitrogen gas charge in a shock absorber prevents oil foaming.
3. Compared to a conventional shock absorber, a heavy-duty shock absorber has:
   A. Triple layers of steel in the lower tube unit.
   B. Higher viscosity oil.
   C. A larger diameter piston rod.
   D. A high-quality seal for longer life.
4. All of these statements about gas-filled shock absorbers are true EXCEPT:
   A. A hydrogen gas charge is used in most shock absorbers and struts.
   B. Gas-filled shock absorbers and struts have an identification label.
   C. New gas-filled shock absorbers are wired in the compressed position.
   D. A gas-filled shock absorber provides continuous damping action with very little wheel movement.
5. The magneto-rheological fluid used in some shock absorbers and struts contains:
   A. Transmission fluid.
   B. Small, suspended metal particles.
   C. Anti-foaming agents.
   D. A dye for lead detection purposes.
6. During normal strut operation:
   A. Downward wheel movement is called wheel jounce.
   B. The strut prevents excessive wheel oscillations.
   C. When the wheel moves upward the strut piston also moves upward.
   D. The strut prevents wheel shimmy.

7. Travel-sensitive struts:
   A. Have an adjustment on the outside of the strut.
   B. Provide more resistance to oil movement when compressed.
   C. Provide more resistance to oil movement when driving on a smooth road surface.
   D. Bypass some of the oil past the piston when compressed.
8. Adjustable struts:
   A. May be adjusted with a control knob in the instrument panel.
   B. Provide five different settings.
   C. Provide softest ride with a No. 1 setting.
   D. Rotate the upper part of the strut to provide adjustable ride quality.
9. Load-leveling shock absorber systems:
   A. May be pressurized from an onboard air pressure tank.
   B. May have a suspension height sensor.
   C. Maintain lower rear suspension height when driving on smooth road surfaces.
   D. Prevent suspension bottoming on rough road surfaces.
10. Electronically controlled shock absorbers and struts:
   A. Contain an electronically controlled actuator in the top of each strut.
   B. Usually have 12 different modes of strut operation from soft to very firm.
   C. Have an electronically controlled actuator that rotates the strut piston rod.
   D. Have an actuator that positions the strut valves to provide more oil restriction in the soft mode.



Chapter 5

Shock Absorber and Strut Diagnosis and Service

Upon completion and review of this chapter, you should be able to:

- Perform a visual shock absorber inspection.
- Perform a shock absorber bounce test, and determine shock absorber condition.
- Determine shock absorber condition from a manual shock absorber test.
- Remove and replace shock absorbers.
- Diagnose shock absorber and strut noise complaints.
- Remove and replace front and rear struts.
- Remove struts from coil springs.
- Install coil springs on struts.
- Follow the vehicle manufacturer's recommended strut disposal procedure.
- Perform off-car strut cartridge replacement procedures.
- Perform on-car strut cartridge replacement procedures.
- Diagnose electrically controlled shock absorbers.

Shock absorbers and struts must be in good condition to provide satisfactory ride quality and maintain vehicle safety. Worn-out shock absorbers and struts may cause excessive chassis oscillations and harsh ride quality with resulting passenger discomfort. On a severely rough road surface, the chassis oscillations caused by worn-out shock absorbers and struts may contribute to a loss of steering control, resulting in a vehicle collision. Therefore, technicians must be familiar with shock absorber and strut diagnosis and service procedures.

BASIC TOOLS

Basic technician's tool set

Service manual

Hydraulic floor jack

Jack stands

Center punch

Shock Absorber Visual Inspection

Bolt Mounting

Shock absorbers should be inspected for loose mounting bolts and worn mounting bushings. If these components are loose, rattling noise is evident, and replacement of the bushings and bolts is necessary.

Bushing Condition

In some shock absorbers, the bushing is permanently mounted in the shock, and the complete unit must be replaced if the bushing is worn. When the mounting bushings are worn, the shock absorber will not provide proper spring control.

SERVICE TIP: During a visual shock absorber inspection, check the rebound, or strikeout, bumpers on the control arms or chassis. If the rebound bumpers are severely worn, the shock absorbers may be worn out.

Oil Leakage

Shock absorbers and **struts** should be inspected for oil leakage. A slight oil film on the lower oil chamber is acceptable. Any indication of oil dripping is not acceptable, and unit replacement is necessary (Figure 5-1).

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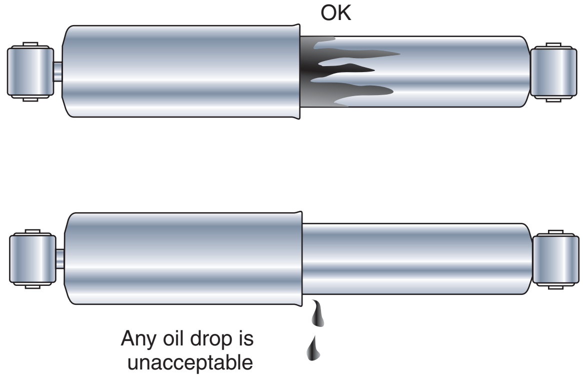


FIGURE 5-1 **Shock absorber and strut oil leak diagnosis.**

Struts are similar internally to shock absorbers, but struts also support the steering knuckle. In many applications, the coil spring is mounted on the strut.

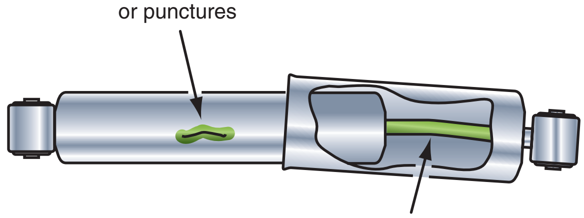


FIGURE 5-2 **Damaged shock absorber inspection.**

A shock absorber may be called a shock.

SERVICE TIP: A road test should be completed to test for shock absorber noise. If the gas leaks out of a shock absorber, oil will leak past the piston and the shock valve may knock (slap) against the oil. This knocking noise is heard when driving the vehicle over small bumps. This noise cannot be duplicated during a bounce test.

Shock absorbers and struts should be inspected visually for physical damage, such as a bent condition and severe dents or punctures. When any of these conditions are present, unit replacement is required (Figure 5-2).

Shock Absorber or Strut Bounce Test

CUSTOMER CARE: Always be willing to spend a few minutes explaining problems, including safety concerns, regarding the customer's vehicle. When customers understand why certain repairs are necessary, they feel better about spending the money. For example, if you explain that worn-out shock absorbers cause excessive chassis oscillations and may result in loss of steering control on irregular road surfaces, the customer is more receptive to spending the money for shock absorber replacement.

When the **bounce test** is performed, the bumper is pushed downward with considerable weight applied on each corner of the vehicle. The bumper is released after this action, and one free upward bounce should stop the vertical chassis movement if the shock absorber or strut provides proper spring control. Shock absorber replacement is required if more than one free upward bounce occurs. The shock absorber bounce test is illustrated in Photo Sequence 7.

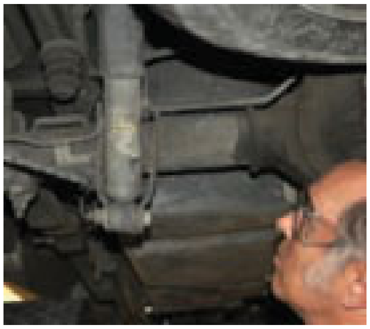
SERVICE TIP: On twin I-beam front suspension systems, front wheel camber may be noticeably different after a bounce test.

Shock Absorber Manual Test

A **manual test** may be performed on shock absorbers. When this test is performed, disconnect the lower end of the shock, and move the shock up and down as rapidly as possible. A satisfactory shock absorber should offer a strong, steady resistance to movement on the entire compression and rebound strokes. The amount of resistance may be different on the compression stroke compared with the rebound stroke. If a loss of resistance is experienced during either stroke, shock replacement is essential.

REAR SHOCK ABSORBER VISUAL INSPECTION AND BOUNCE TEST

P7-1 Raise the vehicle on a lift.



P7-2 Inspect the rear shock absorbers for oil leaks and damage such as dents and punctures.

P7-3 Grasp the lower shock absorber tube and attempt to move the shock absorber vertically and horizontally to check for looseness and wear on the shock absorber bushing and mounting bolt.

P7-4 Grasp the upper shock absorber cover and attempt to move it vertically and horizontally to check for looseness and wear on the shock absorber mounting bushing and mounting bolt.

P7-5 Disconnect the lower shock absorber mounting and grasp the lower end of the shock absorber. Pull the shock absorber downward on the extension stroke and push the lower end of the shock absorber upward on the compression stroke. The shock absorber should offer resistance to movement in relation to the shock absorber ratio.

P7-6 Install the lower shock absorber mounting and tighten the mounting bolt to the specified torque.

P7-7 Lower the vehicle onto the shop floor, and move the vehicle off the lift.

P7-8 Using your knee press down on the rear bumper with considerable weight, and suddenly remove your knee from the bumper. Count the number of free chassis oscillations before the chassis stops bouncing upward and downward.

CAUTION:
Gas-filled shock absorbers will extend when disconnected.

Upward wheel movement is referred to as wheel jounce, and downward wheel movement is called rebound.

Some defective shock absorbers or struts may have internal clunking, clicking, and squawking noises, or binding conditions. When these shock absorber noises or conditions are experienced, shock absorber or strut replacement is necessary.

Air Shock Absorber Diagnosis and Replacement

Air shock absorbers are similar to conventional shocks except they have air pressure applied to them to control chassis curb height. Some air shock absorbers must be pressurized with the shop air hose. This type of unit contains a valve for inflation purposes. Other air shock absorbers are inflated by an onboard compressor with interconnecting plastic lines between the compressor and the shocks. Shock absorber lines must be inspected for breaks, cracks, and sharp bends. If any of these defects are present, the line must be replaced. The shock absorber lines must be secured to the chassis, and they must not rub against other components.

When air shock absorbers slowly lose their air pressure and reduce the curb riding height, shock replacement is required. Before removing an air shock, relieve the air pressure in the shock.

Shock Absorber Replacement

WARNING: Never apply heat to the lower shock absorber or strut chamber with an acetylene torch. Excessive heat may cause a shock absorber or strut explosion, which could result in personal injury.

When shock absorber replacement is necessary, follow this procedure:

1. Before replacing rear shock absorbers, lift the vehicle on a hoist and support the rear axle on safety stands so the shock absorbers are not fully extended.
2. When a front shock absorber must be changed, lift the front end on the vehicle with a floor jack, then place safety stands under the lower control arms. Lower the vehicle onto the safety stands and remove the floor jack.
3. Disconnect the upper shock mounting nut and grommet.
4. Remove the lower shock mounting nut or bolts, and remove the shock absorber.
5. Reverse steps 1 through 4 to install the new shock absorber and grommets.
6. With the full vehicle weight supported on the suspension, tighten the shock mounting nuts to the specified torque.

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Diagnosis of Front Spring and Strut Noise

Strut chatter may be heard when the steering wheel is turned with the vehicle not moving or moving at low speed. To verify the location of this chattering noise, place one hand on a front coil spring while someone turns the steering wheel. If strut chatter is present, the spring binds and releases as it turns. This condition is caused by the upper spring seat binding against the strut bearing mount. A revised spring seat is available to correct this problem on some models.

A noise that occurs on sharp turns or during front suspension jounce may be caused by one of the following problems:

1. Interference between the upper strut rebound stop and the upper mount or **strut tower**
2. Interference between the coil spring and the tower (Figure 5-3)
3. Interference between the coil spring and the upper mount (Figure 5-4)

On some models, these coil spring interference problems may be corrected by installing upper coil spring spacers on top of the coil spring. Spring removal from the strut is required to install these spacers.

A **strut tower** is a raised, circular, reinforced area inboard of the front fenders, which supports the upper end of the strut and coil spring assembly.

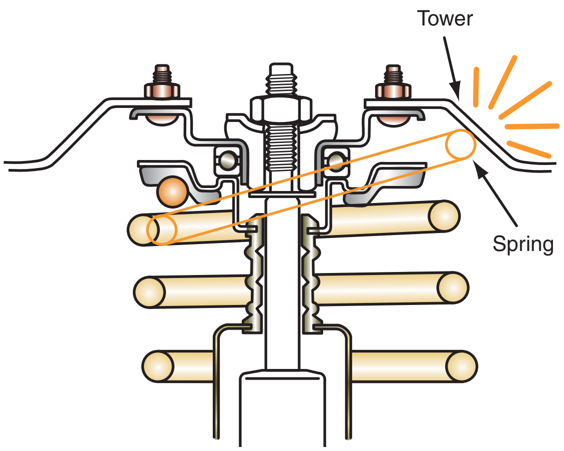

FIGURE 5-3 **Coil spring to upper strut tower interference.**

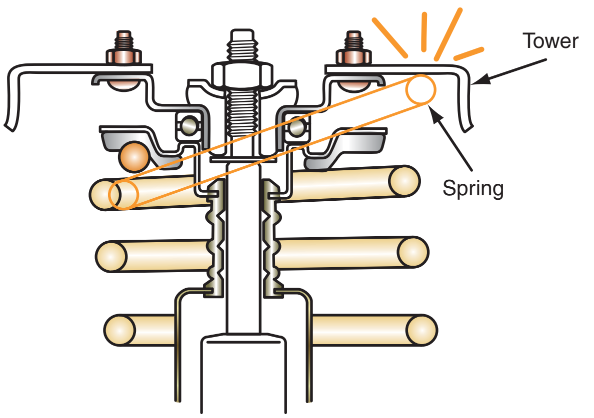

FIGURE 5-4 **Coil spring to upper mount interference.**

On many front suspension systems the strut is bolted to the upper end of the knuckle. When the front wheels are turned, the strut and coil spring rotate together and pivot on the upper strut mount bearing. In this type of suspension, a defective upper strut mount may cause strut chatter and noise.

On other front suspension systems, the strut extends downward and the lower ball joint retains the lower end of the strut to the lower control arm (Figure 5-5). The front hub is bolted to a flange on the knuckle. A bearing assembly is mounted in the lower spring seat. When the front wheels are turned, the strut rotates on the bearing in the lower spring seat, but the spring and upper strut mount do not rotate. Therefore, in this type of suspension system, strut chatter may be caused by a worn or defective lower spring seat bearing.

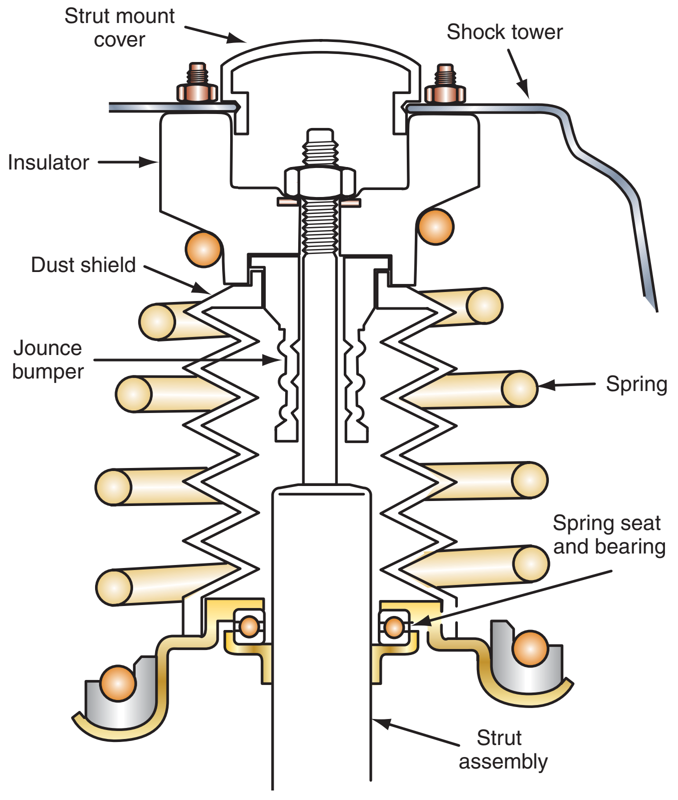

FIGURE 5-5 **Strut assembly with bearing mounted in the lower spring seat.**

An **eccentric camber bolt** has an oblong head, which provides inward or outward steering knuckle movement in relation to the strut as this bolt is rotated.

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If the lateral movement of the strut rod and nut above the strut tower exceeds 3/16 in (4.76 mm), the upper strut bearing and mount assembly should be replaced.

Worn **spring insulators** or broken coil springs cause a rattling noise on road irregularities. Broken coil springs result in reduced curb riding height and harsh riding.

Strut Removal and Replacement

Before a front strut-and-spring assembly is removed, the strut must be removed from the steering knuckle, and the top strut mount bolts must be removed from the strut tower. If an **eccentric camber bolt** is used to attach the strut to the knuckle, always mark the bolt head in relation to the strut and reinstall the bolt in the same position (Figure 5-6).

Always follow the vehicle manufacturer's recommended procedure in the service manual for removal of the strut-and-spring assembly.

A typical procedure for strut-and-spring assembly removal follows:

1. Raise the vehicle on a hoist or floor jack. If a floor jack is used to raise the vehicle, lower the vehicle onto safety stands placed under the chassis so the lower control arms and front wheels drop downward. Remove the floor jack from under the vehicle.
2. Remove the brake line and antilock brake system (ABS) wheel-speed sensor wire from clamps on the strut (Figure 5-7). In some cases, the clamps may also have to be removed from the strut.

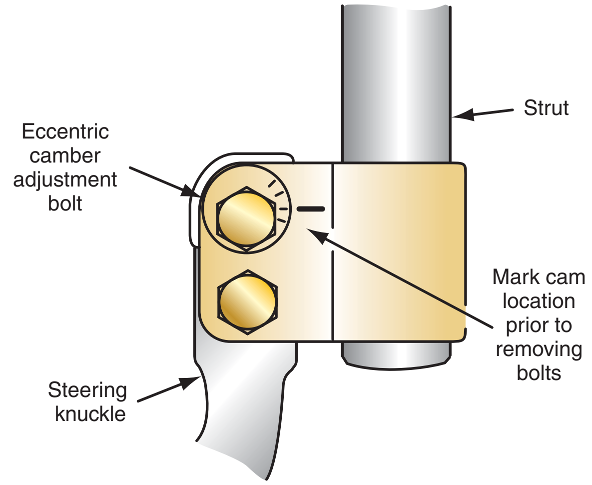

FIGURE 5-6 **Camber bolt marking for strut removal.**

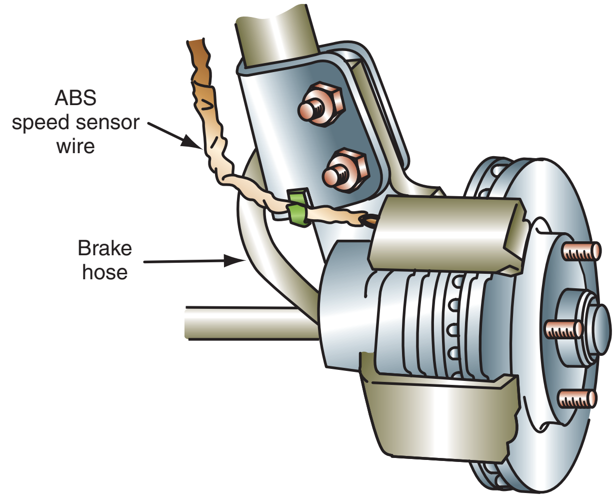

FIGURE 5-7 **Brake line and ABS wheel-speed sensor wire removed from the strut.**

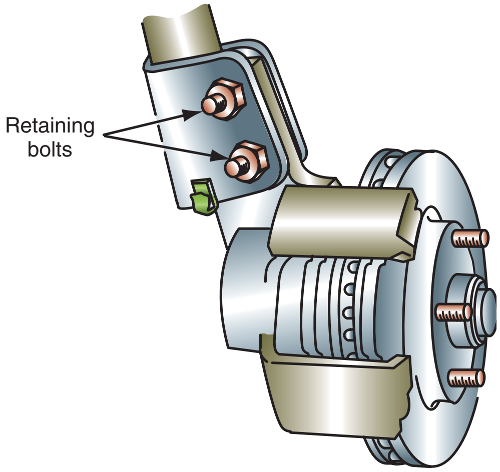

FIGURE 5-8 **Removing strut-to-steering knuckle retaining bolts.**

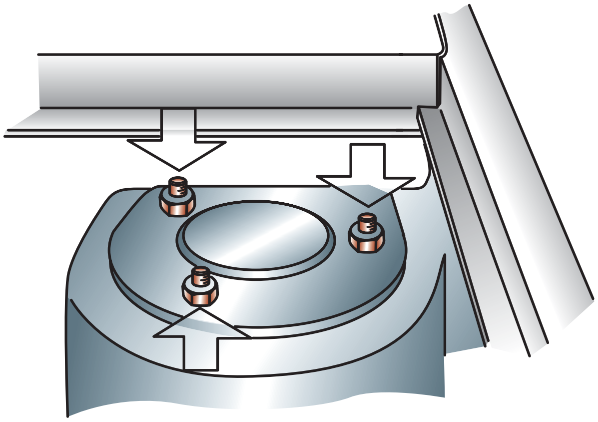

FIGURE 5-9 **Removing upper strut mounting bolts on top of strut tower.**

3. Remove the strut-to-steering knuckle retaining bolts, and remove the strut from the knuckle (Figure 5-8).
4. Remove the upper strut mounting bolts on top of the strut tower, and remove the strut-and-spring assembly (Figure 5-9).

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Removal of Strut from Coil Spring

WARNING: Always use a coil spring compressing tool according to the tool or vehicle manufacturer's recommended service procedure. Be sure the tool is properly installed on the spring. If a coil spring slips off the tool when the spring is compressed, severe personal injury or property damage may occur.

WARNING: Never loosen the upper strut mount retaining nut on the end of the strut rod unless the spring is compressed enough to remove all spring tension from the upper strut mount. If this nut is loosened with spring tension on the upper mount, this mount becomes a very dangerous projectile that may cause serious personal injury or property damage.

SPECIAL TOOLS
Coil spring compressing tool

The coil spring must be compressed with a special tool before the strut can be removed. All the tension must be removed from the upper spring seat before the upper strut piston rod nut is loosened. Many different **spring compressing tools** are available, and they must always be used according to the manufacturer's recommended procedure. *If the coil spring has an enamel-type coating, tape the spring where the compressing tool contacts the spring.* The spring may break prematurely if this coating is chipped.

A typical procedure for removing a strut from a coil spring follows:

1. Install the coil spring and strut assembly in the spring compressing tool according to the tool or vehicle manufacturer's recommended procedure.
2. Adjust the compressing arms on the spring compressing tool so the arms contact the coils farthest away from the center of the spring (Figure 5-10).
3. Turn the handle on top of the compressing tool until all the spring tension is removed from the upper strut mount (Figure 5-10).
4. Loosen and remove the nut on the upper strut rod (Figure 5-11). Be sure all the spring tension is removed from the upper strut mount before loosening this nut.

CAUTION: Never clamp the lower shock absorber or strut chamber in a vise with excessive force. This action may distort the lower chamber and affect piston movement in the shock absorber or strut.

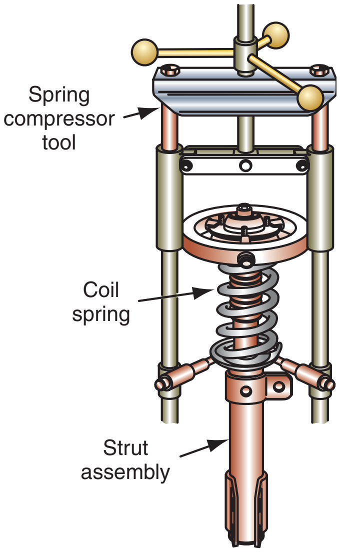

FIGURE 5-10 **Coil spring and strut assembly mounted in a spring compressing tool.**

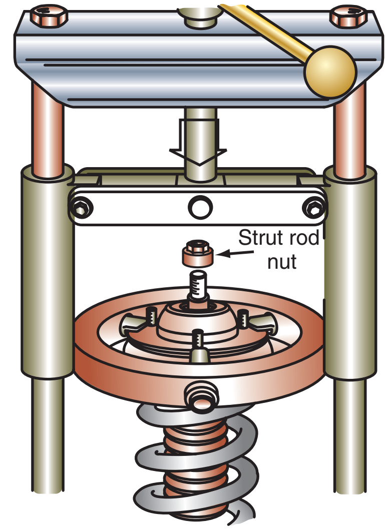

FIGURE 5-11 **After the compressing tool is operated to remove all the spring tension, remove the strut rod nut.**

SERVICE TIP: Because of high labor costs, it is often more economical for the customer if the technician replaces a strut and coil spring as a complete assembly rather than replacing these components individually. Many automotive parts suppliers market struts and coil spring as complete assemblies.

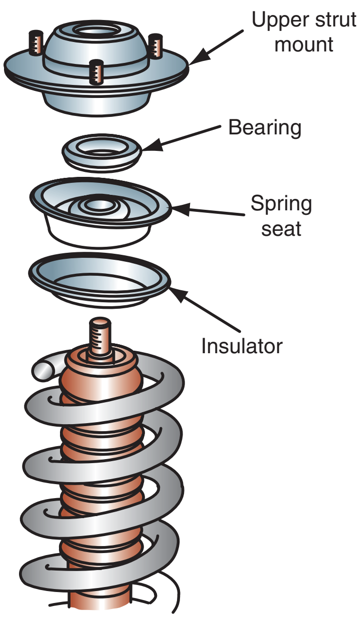

FIGURE 5-12 **Removal of the upper strut mount, bearing, upper spring seat, and insulator.**

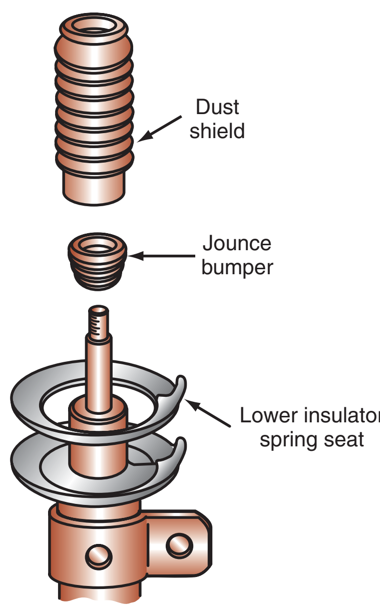

FIGURE 5-13 **Removal of the dust shield, jounce bumper, and lower spring insulator.**

Spring compressing tools are used to compress a coil spring and relieve the spring tension on the upper strut mount to allow spring removal from the strut.

5. Remove the upper strut mount assembly and mount bearing, and then remove the upper spring seat and insulator (Figure 5-12).
6. Rotate the handle on the spring compressing tool to release all the tension on the coil spring, and then remove the spring.
7. Remove the dust shield and jounce bumper from the strut rod, and then remove the lower spring insulator (Figure 5-13).

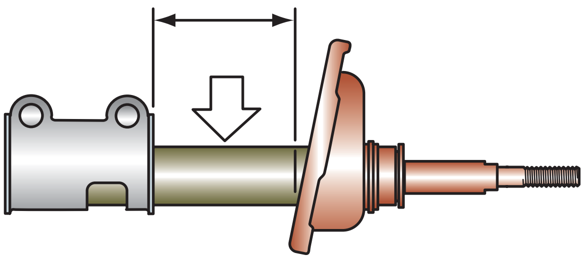

FIGURE 5-14 **Strut drilling location.**

Strut Disposal Procedure

WARNING: Always follow the vehicle manufacturer's recommended procedure for strut disposal. Do not throw gas-filled shock absorbers or struts in a fire of any kind or in a dumpster. If the vehicle manufacturer recommends drilling the strut to release the gas charge, drill the strut at the manufacturer's recommended location.

The following is a typical strut drilling procedure that is performed prior to strut disposal:

1. Fully extend the strut rod.
2. Center punch the strut at the manufacturer's recommended drilling location (Figure 5-14).
3. Drill a small hole at the center-punched position.

Installation of Coil Spring on Strut

A typical procedure for installing a coil spring on a strut follows:

1. Install the lower insulator on the lower strut spring seat, and be sure the insulator is properly seated (Figure 5-15).
2. Install the spring bumper on the strut rod (Figure 5-16).
3. With the coil spring compressed in the spring compressing tool, install the strut in the spring (Figure 5-17). Be sure the spring is properly seated on the lower insulator spring seat.
4. Be sure the strut piston rod is fully extended and install the upper insulator on top of the coil spring.
5. Install the upper strut mount on the upper insulator (Figure 5-18).
6. Be sure the spring, upper insulator, and upper strut mount are properly positioned and seated on the coil spring and strut piston rod (Figure 5-19).
7. Install the strut rod nut, and tighten this nut to the specified torque (Figure 5-20).

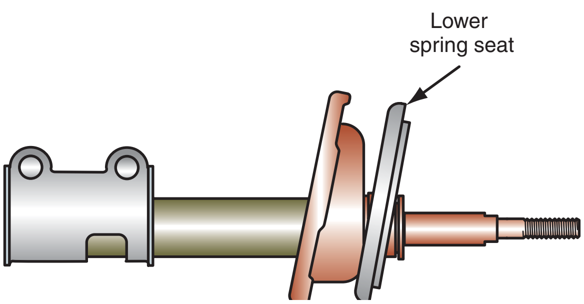

FIGURE 5-15 **Insulator installation on lower spring seat.**

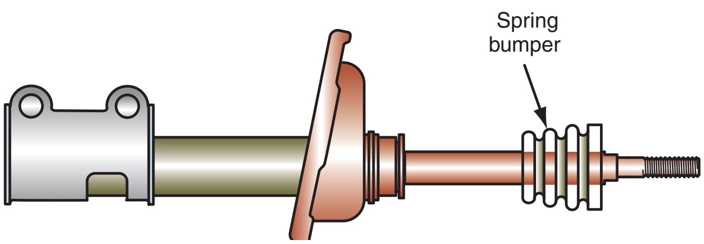

FIGURE 5-16 **Spring bumper installation on strut piston rod.**

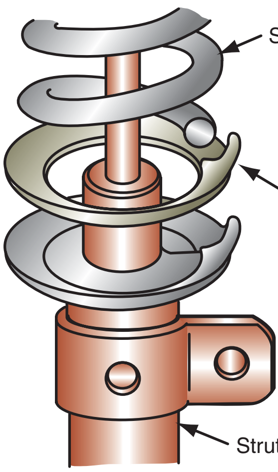

FIGURE 5-17 **Installing strut in coil spring with proper lower spring seat alignment.**

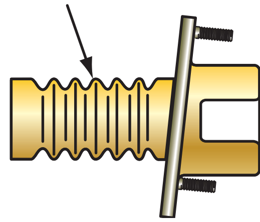

FIGURE 5-18 **Upper insulator and upper strut mount installed on coil spring.**

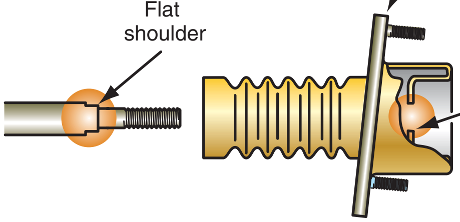

FIGURE 5-19 **Upper strut mount properly positioned on strut piston rod.**

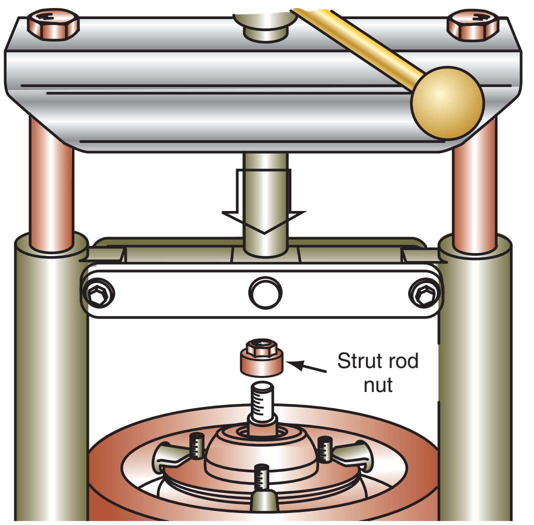

FIGURE 5-20 **Installing strut rod nut.**

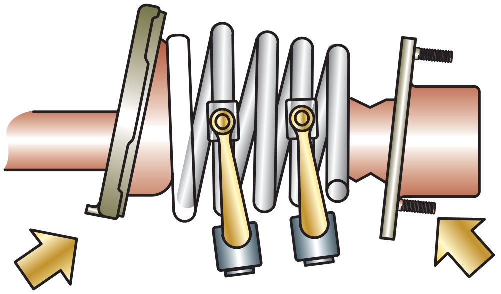
FIGURE 5-21 **Aligning lowest bolt on upper strut mount with tab on lower spring seat.**

8. Rotate the upper strut mount until the lowest bolt in this mount is aligned with the tab on the lower spring seat (Figure 5-21).
9. Gradually loosen the handle on the compressing tool until all the spring tension is released from the tool, and remove the strut and spring assembly from the tool.

Installation of Strut-and-Spring Assembly in Vehicle

A typical installation procedure for a strut-and-spring assembly follows:

1. Install the strut-and-spring assembly with the upper strut mounting bolts extending through the bolt holes in the strut tower. Tighten the nuts on the upper strut mounting bolts to the specified torque (Figure 5-22).
2. Install the lower end of the strut in the steering knuckle to the proper depth, and tighten the strut-to-knuckle retaining bolts to the specified torque (Figure 5-23). If one of the strut-to-knuckle bolts is an eccentric camber bolt, be sure the eccentric is aligned with the mark placed on the strut during the removal procedure.
3. Install the brake hose in the clamp on the strut. Place the ABS wheel-speed sensor wire in the strut clamp if the vehicle is equipped with ABS (Figure 5-24).

Photo Sequence 8 shows a typical procedure for removing and replacing a MacPherson strut.

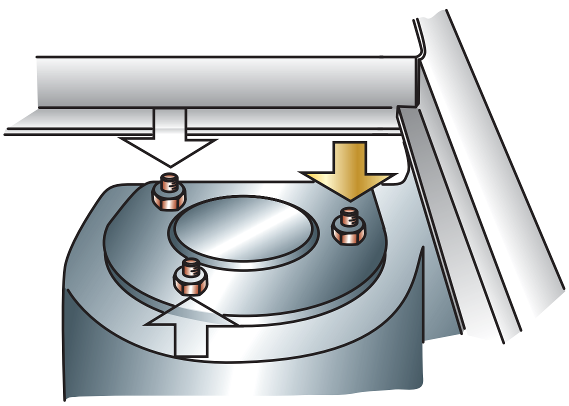

FIGURE 5-22 **Nuts installed on upper strut mount bolts.**

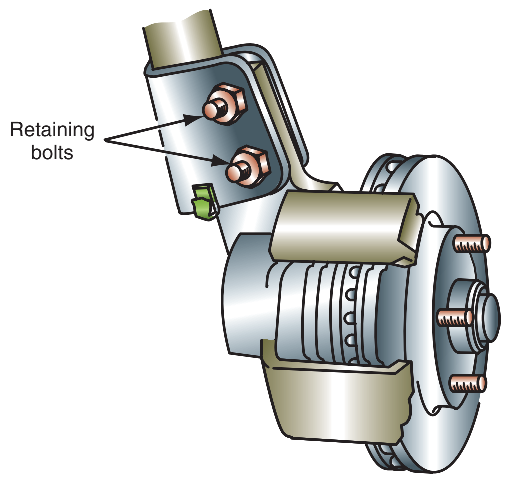

FIGURE 5-23 **Lower end of strut installed in steering knuckle.**

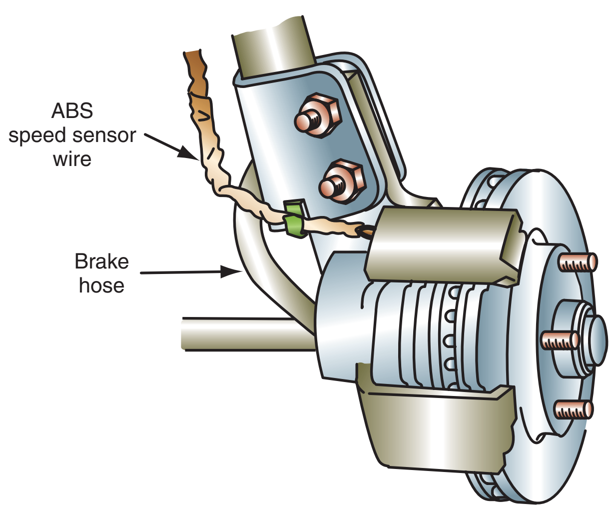

FIGURE 5-24 **Brake hose and ABS wire installed in strut clamps.**

PHOTO SEQUENCE 8

Typical Procedure for Removing and Replacing a MacPherson Strut

P8-1 **The top of the strut assembly is mounted directly to the chassis of the car. Prior to loosening the strut-to chassis bolts, scribe alignment marks on the strut bolts and the chassis.**

P8-2 **With the top strut bolts or nuts removed, raise the car to a working height. It is important that the car be supported on its frame and not on its suspension components.**

P8-3 **Remove the wheel assembly. The strut is accessible from the wheel well after the wheel is removed.**

P8-4 **Remove the bolt that fastens the brake line or hose to the strut assembly.**

P8-5 **Remove the strut-to-steering knuckle bolts.**

P8-6 **Support the steering knuckle with wire and remove the strut assembly from the car.**

P8-7 **Install the strut assembly into the proper type spring compressor. Then compress the spring until all spring tension is removed from the upper strut mount. Loosen and remove the strut rod nut.**

P8-8 **Remove the old strut assembly from the spring and install the new strut. Compress the spring to allow for reassembly and tighten the strut rod nut.**

P8-9 **Reinstall the strut assembly into the car. Make sure all bolts are properly tightened and in the correct locations.**

Rear Strut Replacement

The rear strut replacement procedure varies depending on the type of rear suspension. Always follow the vehicle manufacturer's recommended procedure outlined in the appropriate service manual.

A typical rear strut replacement procedure follows:

1. Lift the vehicle with a floor jack and lower the vehicle onto safety stands placed under the chassis to support the vehicle weight.
2. Place the floor jack under the lower control arm and operate the jack to support some of the spring tension.
3. Remove the tire-and-wheel assembly.
4. Remove the strut-to-spindle bolts.
5. Pull upward on the strut to remove the strut from the spindle. If necessary, lower the floor jack slightly to remove the strut from the spindle.
6. Disconnect the upper strut mount from the chassis, and remove the strut.
7. When the new strut and/or mount is installed, reverse steps 1 through 6. Tighten all the bolts to the specified torque.
8. Check vehicle alignment.

The rear coil springs may be removed from the rear struts using the same basic procedure for spring removal from the front struts.

Installing Strut Cartridge, Off-Car

Customer Care: Check the cost of the strut cartridges versus the price of new struts. Give customers the best value for their repair dollar!

Many struts are a sealed unit, and thus rebuilding is impossible. However, some manufacturers supply a replacement cartridge that may be installed in the strut housing after the strut has been removed from the vehicle. Always follow the **strut cartridge** manufacturer's recommended installation procedure.

A **strut cartridge** contains the inner working part of the strut, which may be installed in the outer housing of the old strut.

The following is a typical off-car strut cartridge installation procedure:

1. Install a bolt and two nuts in the upper strut-to-knuckle mounting bolt hole. Place a nut on the inside and outside of the strut flange.
2. Clamp this bolt in a vise to hold the strut.
3. Locate the line groove near the top of the strut body, and use a pipe cutter installed in this groove to cut the top of the strut body.
4. After the cutting procedure, remove the strut piston assembly from the strut (Figure 5-25).
5. Remove the strut from the vise and dump the oil from the strut.
6. Place the special tool supplied by the vehicle manufacturer or cartridge manufacturer on top of the strut body. Strike the tool with a plastic hammer until the tool shoulder contacts the top of the strut body. This action removes burrs from the strut body and places a slight flare on the body.
7. Remove the tool from the strut body.
8. Install the required amount of oil in the strut, place the new cartridge in the strut body, and turn the cartridge until it settles into indentations in the bottom of the strut body.

SPECIAL TOOLS

Pipe cutter

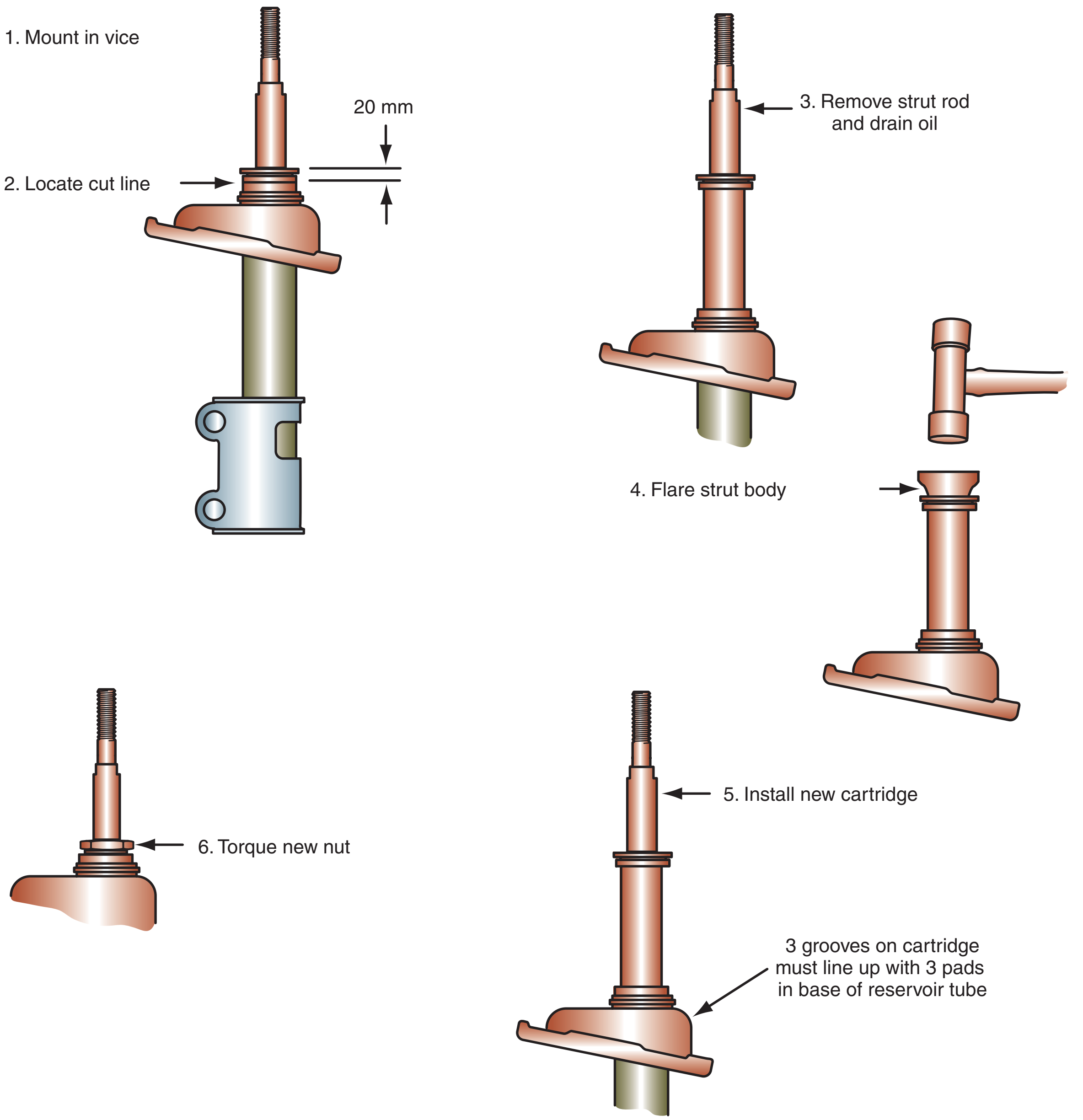

FIGURE 5-25 **Installation of strut cartridge.**

9. Place the new nut over the cartridge.
10. Using a special tool supplied by the vehicle or cartridge manufacturer, tighten the nut to the specified torque.
11. Move the strut piston rod in and out several times to check for proper strut operation.

Installing Strut Cartridge, On-Car

WARNING: If a vehicle is hoisted or lifted in any way during an on-car strut cartridge replacement, the coil spring may fly off the strut, causing vehicle damage and personal injury.

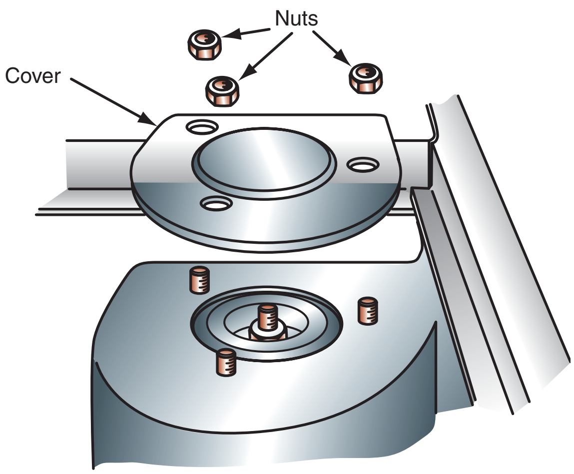

FIGURE 5-26 **Removing upper strut mount nuts and cover.**

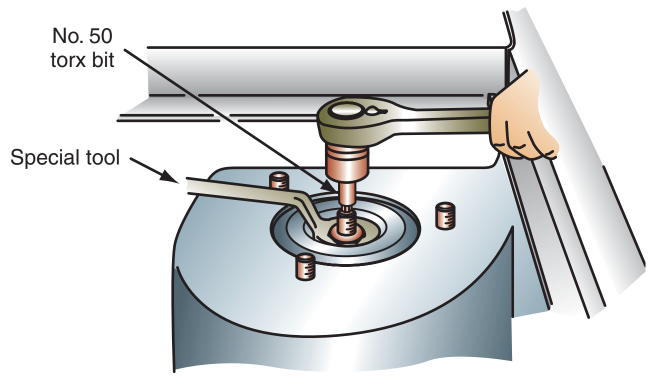

FIGURE 5-27 **Removing nut from strut piston rod.**

On some vehicles, the front strut cartridge may be removed and replaced with the strut installed in the vehicle. Always consult the vehicle manufacturer's service manual for the proper strut service procedure.

A typical on-car strut cartridge installation procedure follows:

1. Remove the nuts from the upper strut mount and remove the strut mount cover (Figure 5-26).
2. Use the special tool supplied by the vehicle manufacturer and a number 50 torx bit to remove the nut from the strut piston rod (Figure 5-27). Never lift or hoist the vehicle once this nut is removed.
3. Remove the bushing from the upper strut mount (Figure 5-28).
4. Thread the special tool supplied by the vehicle manufacturer onto the top of the strut piston rod, and push this rod downward into the strut (Figure 5-29). Remove this tool and then remove the jounce bumper retainer (Figure 5-30).
5. Remove the jounce bumper (Figure 5-31).

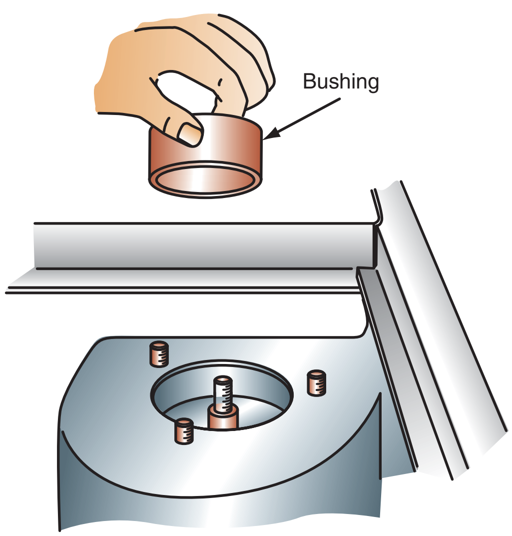

FIGURE 5-28 **Removing upper strut mount bushing.**

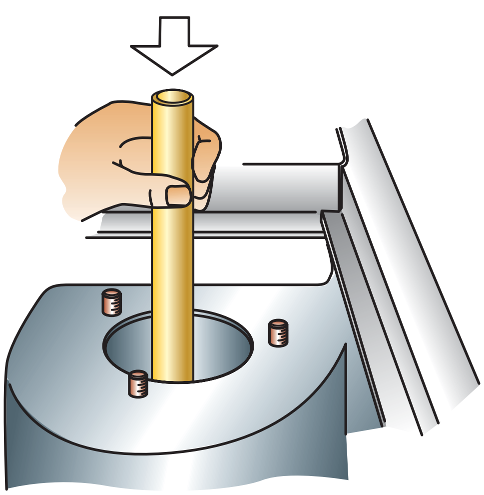
FIGURE 5-29 **Pushing strut piston rod downward.**

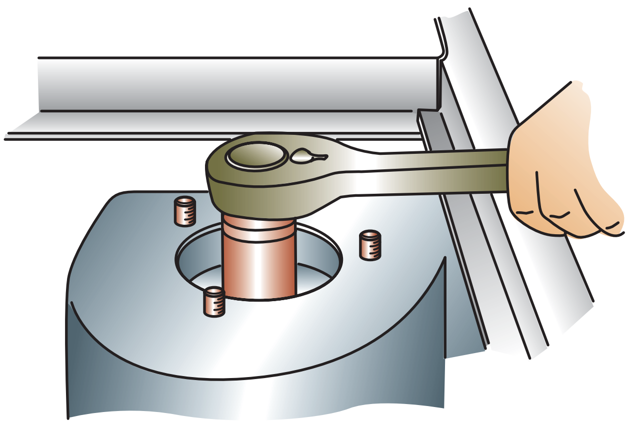

FIGURE 5-30 Removing jounce bumper retainer.

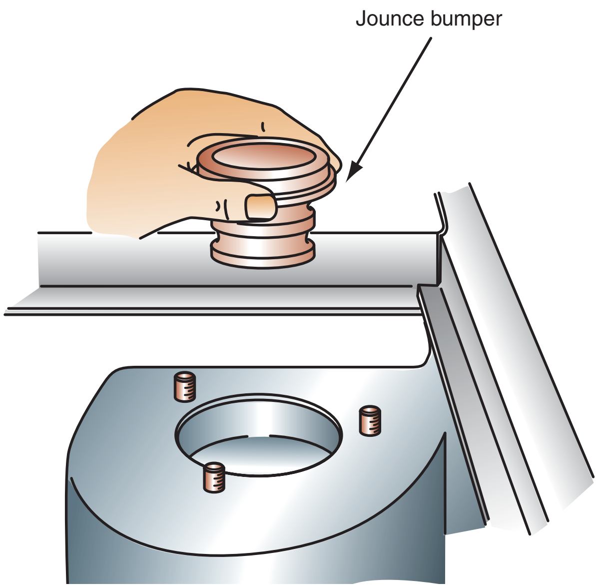

FIGURE 5-31 Removing jounce bumper.

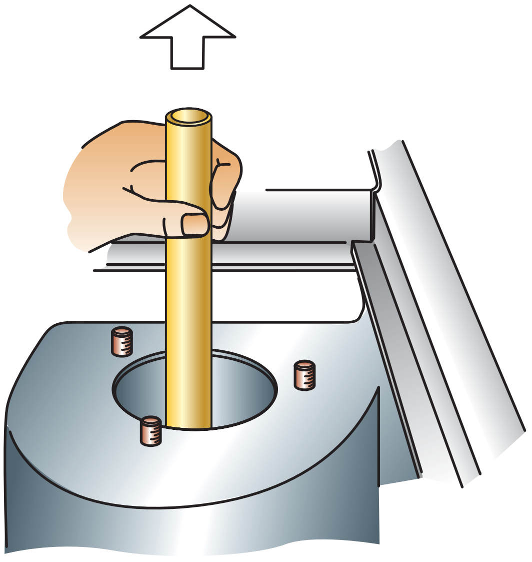

FIGURE 5-32 Re-extending strut piston rod.

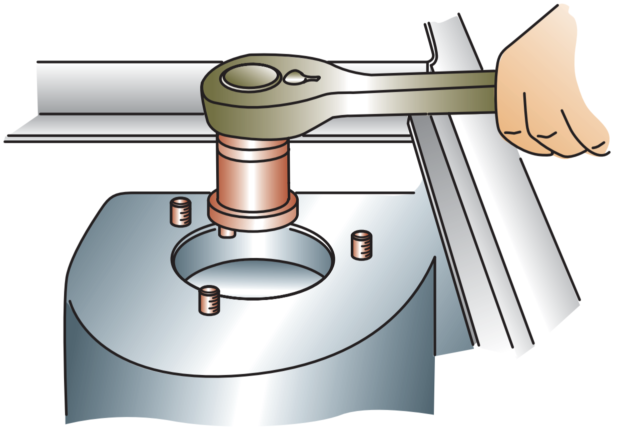

FIGURE 5-33 Removing strut closure nut.

6. Thread the special tool onto the strut piston rod, and re-extend this rod (Figure 5-32). Use the special tool supplied by the vehicle manufacturer to remove the closure nut on top of the strut (Figure 5-33).
7. Grasp the top of the strut piston rod and remove the strut valve mechanism (Figure 5-34).
8. Remove the oil from the strut tube with a hand-operated suction pump.
9. Install the new strut cartridge in the strut, and tighten the closure nut to the specified torque (Figure 5-35). Reverse steps 1 through 6 to complete the strut cartridge replacement. Place a light coating of the vehicle manufacturer's recommended engine oil on the upper strut mount bushing prior to bushing installation.

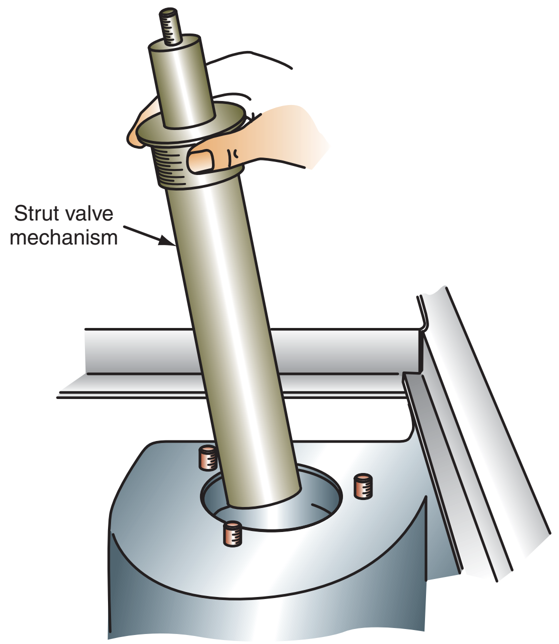

FIGURE 5-34 **Removing strut valve mechanism.**

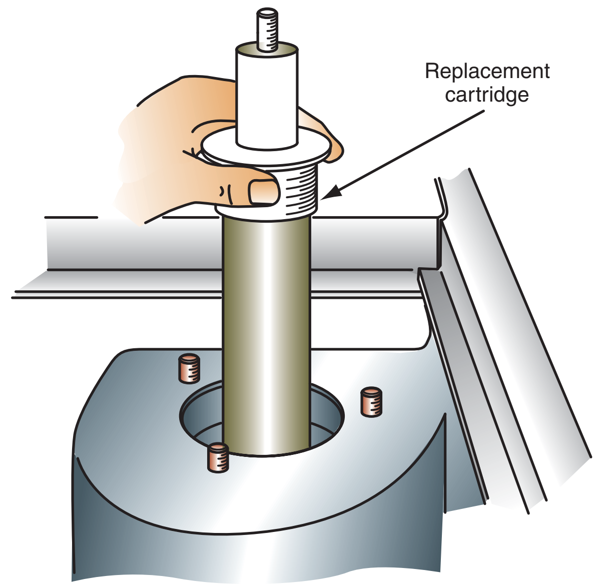

FIGURE 5-35 **Installing new strut cartridge.**

Diagnosis of Electronically Controlled Shock Absorbers

An actuator may be called a solenoid.

The actuators on electronically controlled shock absorbers can be removed by pushing inward simultaneously on the two actuator retaining tabs and lifting the actuator off the top of the strut (Figure 5-36).

WARNING: If the strut piston rod nut and actuator mounting bracket are removed, do not move or raise the vehicle. This action releases the coil spring tension and may result in personal injury and vehicle damage.

Follow these steps to diagnose the electronic actuator:

1. With the actuator removed from the strut and the actuator wiring harness connected, turn the ignition switch on. Move the ride control switch to the auto position and wait 5 seconds.

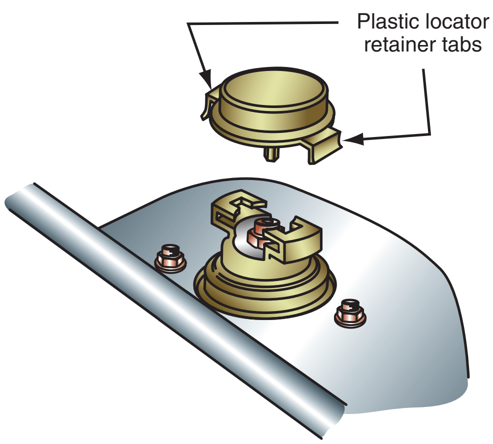

FIGURE 5-36 **Electronically controlled strut actuator.**

2. Move the ride control switch to the firm position, and wait 5 seconds. If the actuator control tube on the bottom of the actuator rotated, the actuator is operating. If the actuator control tube did not rotate, proceed with the actuator tests.
3. With the ride control switch in the firm position, place matching H's beside the control tube and the actuator.
4. With the ride control switch in the auto position, place matching S's beside the control tube and the actuator.
5. Turn the ignition switch off and disconnect the actuator electrical connector. The actuator control tube may be rotated with a small screwdriver.
6. Connect a pair of ohmmeter leads to the position sense wire and the signal return wire. The position sense wire is white or white with a colored tracer, and the signal return wire is yellow with a black tracer. With the actuator in the S position, the position sense should be closed and the ohmmeter should indicate less than 10 ohms.
7. Rotate the actuator to the H position. Under this condition, the position sense switch should be open and the ohmmeter should indicate over 1,000 ohms. If the ohmmeter readings are not within specifications, replace the actuator.
8. Connect the ohmmeter leads to the position sense wire and soft power terminal in the actuator electrical connector. The position sense wire is white or white with a colored tracer, and the soft power wire is tan with a red tracer. If the ohmmeter indicates over 1,000 ohms, the actuator is satisfactory. If the ohmmeter reading is below 10 ohms, replace the actuator.
9. Connect the ohmmeter leads from the signal return terminal in the wiring harness side of the actuator connector to a chassis ground. The ohmmeter should indicate less than 10 ohms. If the ohmmeter reading is higher than specified, check the signal return wire and the programmed ride control (PRC) module.

SERVICE TIP:
Wiring harness colors vary depending on the vehicle make and model year. The wiring colors in the following steps are based on Ford vehicles. If you are working on a different make of vehicle, refer to the wire colors in the vehicle manufacturer's service information.

TABLE 5-1 **SHOCK ABSORBER AND STRUT DIAGNOSIS**

Problem	Symptoms	Possible Causes
Harsh ride quality	Excessive chassis bouncing Excessive vertical wheel oscillations	Worn out shock absorbers or struts
Shock absorber or strut oil leaks	Oil dripping from shock absorber or strut	Worn out seal in shock absorber or strut, damaged lower shock absorber or strut housing
Rattling noise	Rattling noise in chassis when driving	Worn out shock absorber or strut mountings
Chattering noise	Chattering noise when turning the front wheels to the right or left	Worn out upper strut mount and bearing assembly
Worn, damaged rebound bumpers	Chassis bottoming out	Worn out shock absorbers or struts, low ride height

CASE STUDY

A customer complained about a squeaking noise in the rear suspension of a 2009 Dodge Caravan. The customer said the noise occurred during normal driving at lower speeds. The technician lifted the car on a hoist and made a check of all rear suspension bushings in shock absorbers, track bar, and trailing arms. The spring insulators and all suspension bolts were checked visually. All of these items were in good condition, and there was no evidence of a squeaking noise as the chassis was bounced gently. Since the exact source of chassis noise can sometimes be difficult to locate, the technician performed a visual check of

bushings, insulators, and fasteners in the front suspension. No problems were found in the front suspension.

One of the first requirements for successful automotive diagnosis is to obtain as much information as possible from the customer. The customer with the squeaking rear suspension in a Dodge Caravan lived in a part of the country where cold temperatures occur in the winter. This complaint occurred in January. The technician questioned the customer further about the conditions when the squeaking suspension noise was heard, and the customer revealed that the noise occurred when the temperature was severely cold. The customer also indicated that the noise disappeared at warmer temperatures.

The technician informed the customer that the only way to find the exact cause of this annoying squeak was to leave the car on the lot at the shop all night and check it first thing in the morning when it was colder. The customer complied with this suggestion, and the technician drove the car into the shop immediately the next morning. The squeaking noise occurred as the car was driven across the parking lot. The technician lifted the car on a hoist and listened with a stethoscope at each rear suspension bushing as a coworker gently bounced the rear suspension. No squeaking noise was heard at any of the rear suspension bushings. However, when the stethoscope pickup was placed on the left rear shock absorber, the squeaking noise was loud and clear. The shock absorber was quickly removed, and the squeaking noise was gone when the rear chassis was bounced gently. Replacement of the left rear shock absorber corrected this complaint and made the customer happy.

Terms to Know

Bounce test
Eccentric camber bolt
Manual test
Spring compressing tools
Spring insulators
Struts
Strut cartridge
Strut chatter
Strut tower

ASE-Style Review Questions

1. A slight oil film appears on the lower shock absorber oil chamber, and the shock absorber performs satisfactorily in a bounce test:

   Technician A says the shock absorber is satisfactory.

   Technician B says the shock absorber may contain excessive pressure.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While discussing a shock absorber and strut bounce test:

   Technician A says the shock absorber is satisfactory if the bumper makes two free upward bounces.

   Technician B says the bumper must be pushed downward with considerable force.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. While discussing a shock absorber manual test:

   Technician A says the shock absorber's resistance to movement should be jerky and erratic.

   Technician B says the shock absorber's resistance to movement may be greater on the rebound stroke compared with the compression stroke.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. When the front wheels are turned on a vehicle equipped with front struts, the left front coil spring provides a chattering action and noise:

   Technician A says the strut has internal defects, and strut replacement is necessary.

   Technician B says the upper strut bearing and mount is defective.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

5. While discussing enamel-coated coil springs:

   Technician A says if the enamel-type coating on a coil spring is chipped, the spring may break prematurely.

   Technician B says coil springs should be taped in the compressing tool contact areas to prevent chipping of the enamel-type coating.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

6. During service procedures, gas-filled shock absorbers may:

   A. Be heated with an acetylene torch.
   B. Be thrown in an incinerator.
   C. Extend when disconnected.
   D. Retract when disconnected and extended.

7. During wheel jounce, a thumping noise is heard in the right front suspension, but the strut bounce test is satisfactory. All of these defects could cause the problem EXCEPT:
   A. A worn upper strut mount.
   B. Worn spring insulators.
   C. A broken coil spring.
   D. A fluid leak in the strut.
8. When removing and replacing a front strut on a MacPherson strut suspension:
   A. The cam-type strut-to-knuckle bolt should be marked in relation to the strut.
   B. The strut rod nut may be loosened with spring tension applied to the upper strut mount.
   C. The lower strut chamber may be clamped in a vise to support the strut.
   D. The spring compressor must be installed before the strut is removed from the vehicle.
9. When assembling and installing a strut and coil spring in a MacPherson strut front suspension:
   A. The upper spring insulator should be installed between the upper strut mount and the strut tower.
   B. The lower spring insulator should be installed between the coil spring and the spring bumper.
   C. On some vehicles, the upper strut mount must be properly aligned in relation to the lower spring seat on the strut.
   D. Final compressing of the coil spring may be done by tightening the nut on the strut rod.
10. During an on-car strut cartridge replacement:
   A. Oil must be removed from the strut with a hand-operated suction pump.
   B. The front suspension may be lifted with a floor jack.
   C. The strut rod must be pulled upward before removing the jounce bumper.
   D. The new strut cartridge must be filled with the manufacturer's specified fluid.

ASE Challenge Questions

1. A customer says his MacPherson strut front suspension is making a chattering noise when the steering wheel is turned hard to the left. He says he also feels a "kind of vibration" in the steering wheel when the chatter is heard. To correct this problem, you should:
   A. Replace the front struts.
   B. Check the lower strut spring seating.
   C. Check the stabilizer links.
   D. Check the upper bearing and strut mounting.
2. When performing a bounce test on a twin I-beam front suspension, the front tires noticeably flex as the front end of the vehicle is vigorously exercised. When the vehicle is released, the front end rebounds once then settles, but the front wheel now has a slight but obvious negative camber.

   Technician A says the shock absorbers are worn and should be replaced.

   Technician B says the twin I-beam suspension can change camber during a bounce and rebound.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B
3. The front rebound bumpers on a coil spring suspension system are badly worn and damaged.

   Technician A says the shock absorbers may be worn out.

   Technician B says the coil springs may be weak.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B
4. A manual test of a shock absorber shows a stronger resistance to rebound than compression.

   Technician A says the shock is defective.

   Technician B says the shock has a 50/50 ratio.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B
5. *Technician A* says any visible presence of oil on a strut or shock requires replacement.

   Technician B says a slight film of oil on a strut or shock is OK if it performs satisfactorily in a bounce test.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

Name ______________________________ Date ____________________

Remove Strut-and-Spring Assembly and Disassemble Strut and Spring

Upon completion of this job sheet, you should be able to remove a strut-and-spring assembly from a car and disassemble the strut and spring.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task C-10. Remove, inspect, and install strut cartridge or assembly, strut coil spring, insulators (silencers), and upper strut bearing mount.

Tools and Materials

Front-wheel-drive car
Floor jack
Safety stands
Coil spring compressor

Describe the Vehicle Being Worked On:

Year ________ Make ________________ Model ______________________
VIN ________________________ Engine type and size ________________

Procedure

Task Completed

1. With the vehicle parked on the shop floor, perform a strut bounce test.

   Based on the bounce test results, state the strut condition, and give the reason for your diagnosis.

   ____
   ____

2. Raise the vehicle on a hoist or with a floor jack. If a floor jack is used to raise the vehicle, lower the vehicle onto safety stands placed under the chassis so the lower control arms and front wheels drop downward. Remove the floor jack from under the vehicle.

   Is the vehicle securely supported on safety stands? ☐ Yes ☐ No

   Instructor check ____

3. Remove the brake line and antilock brake system (ABS) wheel-speed sensor wire from clamps on the strut. In some cases, these clamps may have to be removed from the strut.

   Is the brake line and ABS wheel-speed sensor wire disconnected? ☐ Yes ☐ No

   Instructor check ____

Task Completed

4. Punch mark the cam bolt in relation to the strut, remove the strut-to-steering knuckle retaining bolts, and remove the strut from the knuckle.

Is the cam bolt marked in relation to the strut? ☐ Yes ☐ No

Is the strut removed from the knuckle? ☐ Yes ☐ No

Instructor check ____________________

State the reason for marking the cam bolt in relation to the strut.

____

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☐ 5. Remove the upper strut mounting bolts on top of the strut tower; remove the strut-and-spring assembly.

WARNING: Always use a coil spring compressing tool according to the tool or vehicle manufacturer's recommended service procedure. Be sure the tool is properly installed on the spring. If a coil spring slips off the tool when the spring is compressed, severe personal injury or property damage may occur.

WARNING: Never loosen the upper strut mount retaining nut on the end of the strut rod unless the spring is compressed enough to remove all spring tension from the upper strut mount. If this nut is loosened with spring tension on the upper mount, this mount becomes a very dangerous projectile that may cause serious personal injury or property damage.

CAUTION: Never clamp the lower shock absorber or strut chamber in a vise with excessive force. This action may distort the lower chamber and affect piston movement in the shock absorber or strut.

6. Install the spring compressing tool on the coil spring according to the tool or vehicle manufacturer's recommended procedure.

Is the compressing tool properly installed on the strut-and-spring assembly?
☐ Yes ☐ No

Instructor check ____________________

☐ 7. Turn the nut on top of the compressing tool until all the spring tension is removed from the upper strut mount.

Is all the spring tension removed from the upper strut mount? ☐ Yes ☐ No

Instructor check ____________________

CAUTION: If the coil spring has an enamel-type coating and the compressing tool contacts the coil spring, tape the spring where the compressing tool contacts the spring.

☐ 8. Install a bolt and two nuts in the upper strut to knuckle mounting bolt holes. Install a nut on each side of the strut flange. Clamp this bolt securely in a vise to hold the strut-and-spring assembly and the compressing tool.

9. Use the bar on the spring compressing tool to hold the strut-and-spring assembly from turning, and loosen the nut on the upper strut mount. Be sure all the spring tension is removed from the upper strut mount before loosening this nut.

Is all the spring tension removed from the upper strut mount? ☐ Yes ☐ No

Is the upper strut mount retaining nut loosened? ☐ Yes ☐ No

Instructor check ____________________

10. Remove the nut, upper strut mount, upper insulator, coil spring, spring bumper, and lower insulator.

Task Completed ☐

11. Inspect the strut, upper strut mount, coil spring, spring insulators, and spring bumper. On the basis of this inspection, list the necessary strut-and-spring service, and give the reasons for your diagnosis.

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Instructor's Response ____

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Name ______________________ Date ______________

Assemble Strut and Spring and Install Strut-and-Spring Assembly

Upon completion of this job sheet, you should be able to assemble a strut and spring and install a strut-and-spring assembly in a car.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task C-10: Remove, inspect, and instoll strut cartridge on assembly, strut coil spring, insulators (silencers), and upper strut bearing mount.

Tools and Materials

Front-wheel-drive car
Floor jack
Safety stands
Coil spring compressor

Describe the Vehicle Being Worked On:

Year __________ Make ______________ Model ______________________
VIN ______________________ Engine type and size ______________________

Procedure

Task Completed

1. Install a bolt in the upper strut-to-knuckle retaining bolt, and clamp this bolt in a vise to hold the strut, spring, and compressing tool as in the disassembly procedure. ☐
2. Install the lower insulator on the lower strut spring seat and be sure the insulator is properly seated.

   Is the lower insulator properly seated? ☐ Yes ☐ No

   Instructor check ______________________
3. Install the spring bumper on the strut rod.

   Is the spring bumper properly installed? ☐ Yes ☐ No

   Instructor check ______________________
4. With the coil spring compressed in the spring compressing tool, install the spring on the strut. Be sure the spring is properly seated on the lower insulator spring seat.

   Is the coil spring properly seated on the lower insulator? ☐ Yes ☐ No

   Instructor check ______________________

Task Completed

☐

5. Be sure the strut piston rod is fully extended and install the upper insulator on top of the coil spring.

   Is the strut rod fully extended? ☐ Yes ☐ No

   Is the upper insulator properly installed? ☐ Yes ☐ No

   Instructor check ________________

6. Install the upper strut mount on the upper insulator.

7. Be sure the spring, upper insulator, and upper strut mount are properly positioned and seated on the coil spring and strut piston rod.

   Are the spring, upper insulator, and upper strut mount properly positioned?
   ☐ Yes ☐ No

   Instructor check ________________

8. Use the compressing tool bar to hold the strut and spring from turning, then tighten the strut piston rod nut to the specified torque.

   Specified strut piston rod nut torque ________________

   Actual strut piston rod nut torque ________________

9. Rotate the upper strut mount until the lowest bolt in this mount is aligned with the tab on the lower spring seat.

   Is the upper strut mount properly aligned? ☐ Yes ☐ No

   Instructor check ________________

☐

10. Gradually loosen the nut on the compressing tool until all the spring tension is released from the tool, and remove the tool from the spring.

11. Install the strut-and-spring assembly with the upper strut mounting bolts extending through the bolt holes in the strut tower. Tighten the nuts on the upper strut mounting bolts to the specified torque.

    Specified upper strut mount nut torque ________________

    Actual upper strut mount nut torque ________________

12. Install the lower end of the strut in the steering knuckle to the proper depth. Align the punch marks on the cam bolt and strut that were placed on these components during disassembly, and tighten the strut-to-knuckle retaining bolts to the specified torque.

    Is the cam bolt properly positioned? ☐ Yes ☐ No

    Specified strut-to-knuckle bolt torque ________________

    Actual strut-to-knuckle bolt torque ________________

    Instructor check ________________

Task Completed

13. Install the brake hose in the clamp on the strut. Place the ABS wheel-speed sensor wire in the strut clamp if the vehicle is equipped with ABS.

    Is the brake hose properly installed and tightened? ☐ Yes ☐ No

    Is the ABS wheel-speed sensor properly installed and tightened? ☐ Yes ☐ No

    Instructor check ________________________________

14. Raise the vehicle with a floor jack, remove the safety stands, and lower the vehicle onto the shop floor. ☐

Instructor's Response ________________________________

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Name ______________________________ **Date** ____________________

INSTALL STRUT CARTRIDGE OFF-CAR

Upon completion of this job sheet, you should be able to remove and replace a strut cartridge with the strut removed from the car.

NATEF Correlation

This job sheet is related to the NATEF Suspension and Steering Task C-10. Remove, inspect, and install strut cartridge on assembly, strut coil spring, insulators (silencers), and upper strut bearing mount.

Tools and Materials

Front strut removed from car

Pipe cutter

Torque wrench

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ___________________________

VIN ______________________________ Engine type and size _______________________

Procedure | Task Completed

1. List the strut conditions and suspension operating conditions that indicate a strut should be serviced or replaced.

   ____

   ____

   ____

   ____

2. Install a bolt and two nuts in the upper strut to knuckle mounting bolt hole. Place a nut on the inside and outside of the strut flange. ☐
3. Clamp this bolt in a vise to hold the strut.
4. Locate the line groove near the top of the strut body, and use a pipe cutter installed in this groove to cut the top of the strut body. ☐
5. After the cutting procedure, remove the strut piston assembly from the strut.

   Is the strut piston assembly removed from the strut? ☐ Yes ☐ No

   Instructor check ____

6. Remove the strut from the vise and dump the oil from the strut. ☐

Task Completed

7. Place the special tool supplied by the vehicle manufacturer or cartridge manufacturer on top of the strut body and strike the tool with a plastic hammer until the tool shoulder contacts the top of the strut body. This action removes burrs from the strut body and places a slight flare on the body.

   Is the strut body properly flared? ☐ Yes ☐ No

   Instructor check ______________________________

☐ 8. Remove the tool from the strut body.

9. Place the new cartridge in the strut body and turn the cartridge until it settles into indentations in the bottom of the strut body.

   Is the new strut cartridge properly seated in strut body indentations? ☐ Yes ☐ No

   Instructor check ______________________________

☐ 10. Place the new nut over the cartridge.

11. Using a special tool supplied by the vehicle or cartridge manufacturer, tighten the nut to the specified torque.

   Specified strut nut torque ____________________

   Actual strut nut torque ____________________

12. Move the strut piston rod in and out several times to check for proper strut operation.

   Strut operation: ☐ Satisfactory ☐ Unsatisfactory

Instructor's Response ______________________________

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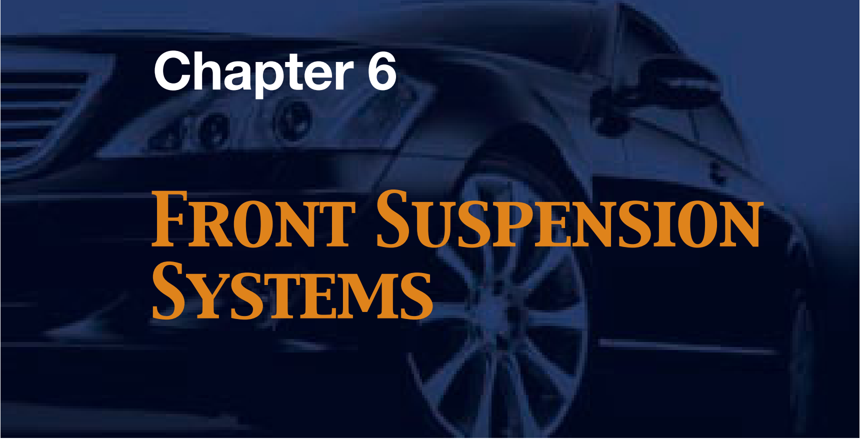

Chapter 6

Front Suspension Systems

Upon completion and review of this chapter, you should be able to understand and describe:

- The causes of coil spring failure.
- The design and spring rate of a linear-rate coil spring.
- The difference between a regular-duty coil spring and a heavy-duty coil spring.
- The functions of three different types of coils in a variable-rate coil spring.
- Basic torsion bar action as a front wheel strikes a road irregularity.
- How friction and noise problems are reduced in a multiple-leaf spring.
- The advantages of a front suspension system with ball joints compared to earlier I-beam front suspension systems.
- Two types of load-carrying ball joints, and explain the location of the control arm in each type.
- How you would recognize a worn ball joint from a visual inspection of the ball joint wear indicator.
- The mounting location and purpose of a stabilizer bar.
- The purpose of a strut rod.
- The two steering knuckle pivot points in a MacPherson strut front suspension system.
- The advantage of a short-and-long arm front suspension system compared with a suspension system with equal-length upper and lower control arms.
- Two methods of attaching the spindles to the I-beams in a twin I-beam front suspension.
- The effect of sagged front springs on caster angle and directional stability.
- The effect of sagged front springs on camber angle.
- The advantages of hydraulic control arm bushings.
- The advantages of aluminum control arms.

Introduction

The front and rear suspension systems must perform several extremely important functions to maintain vehicle safety and owner satisfaction. The suspension system must supply steering control for the driver under all road conditions. Vehicle owners expect the suspension system to provide a comfortable ride. The suspension, together with the frame, must maintain proper vehicle tracking and directional stability. Another important purpose of the suspension system is to provide proper wheel alignment and minimize tire wear.

The impact of the front tires striking road irregularities must be absorbed and dissipated by the front suspension system. These impacts are distributed throughout the suspension, and this action isolates the vehicle passengers from road shock. The vehicle's ride characteristics are determined by the amount of impact energy that the suspension can absorb and by the

rate at which the suspension dissipates these tire impacts. Ride characteristics are designed into the suspension system, and these characteristics are not adjustable. For example, the front suspension may be designed to provide a very soft ride in which all the tire impacts are absorbed and dissipated quickly by the suspension system. This type of suspension system provides a very comfortable ride, but it also allows excessive body lean during cornering, which reduces high-speed cornering and handling capabilities. Such vehicles as sports cars and sport utility vehicles (SUVs) are usually designed with a suspension system that provides a firm ride and absorbs and dissipates tire impacts more slowly. Although high-speed cornering and handling capabilities are improved, this type of suspension may transfer some road shock to the passenger compartment.

When the vehicle is driven over road irregularities, the front suspension system must allow the front wheels to move vertically while maintaining the tire's proper horizontal position in relation to the road surface. To provide this wheel action, the steering knuckle must be mounted between the upper and lower control arms on short-and-long arm (SLA) suspension systems or between the lower control arm and the lower end of the strut on MacPherson strut suspension systems. The upper and lower control arms must be pivoted on the inner ends; the steering knuckle pivots on the ball joints in SLA suspensions or on the lower ball joint and upper strut mount on MacPherson strut suspensions.

Coil springs absorb much of the shock from tire impacts with the road surface. When a front wheel strikes a road irregularity and moves upward, the coil spring compresses and absorbs energy during this movement. The coil spring immediately dissipates this energy as the spring moves back to its original state. Shock absorbers are installed in the front suspension system to dampen the oscillations of the coil springs.

A stabilizer bar is mounted on rubber insulating bushings and bolted to the chassis. The outer ends of the stabilizer bar are attached through links to the lower control arms. The stabilizer bar controls the amount of independent lower control arm movement. When one front wheel strikes a road irregularity and moves upward, the stabilizer bar transfers part of the lower control arm movement to the opposite lower control arm, which reduces and stabilizes body roll. Therefore, the stabilizer bar helps to define the suspension characteristics related to body roll.

All suspension components, including the frame and chassis, are designed or "tuned" to provide the ride and handling qualities that the manufacturer believes the average driver will desire. For example, the late model Explorer Sport Trac frame has been stiffened 40 percent more than the Explorer frame. To achieve this increased stiffness, the frame side rails are thicker than the ones on the Explorer, and a new tubular crossmember has been added to the frame. **Gussets** have also been welded into the corners where the crossmembers meet the side rails. This frame design is matched to the torsion bar suspension to provide improved vehicle agility on and off the road.

Gussets are pieces of metal welded into the corner where two pieces of metal are attached together, which provide increased strength and stiffness.

Suspension System Components

Coil Springs

The coil spring is the most commonly used spring for front and rear suspension systems. Coil springs are actually a coiled-spring steel bar. When a vehicle wheel strikes a road irregularity, the coil spring compresses to absorb shock, and then recoils back to its original installed height. Many coil springs contain a steel alloy that contains different types of steel mixed with other elements such as silicon or chromium. Coil springs may be manufactured by a cold or hot coiling process. The hot coiling process includes procedures for tempering and hardening the steel alloy. Coil springs are designed to carry heavy loads, but they must be light in weight. Many coil springs have a vinyl coating, which increases corrosion resistance and reduces noise.

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Coil spring failures may be caused by these conditions:

1. Constant overloading
2. Continual jounce and rebound action
3. Metal fatigue
4. A crack or nick on the surface layer or coating

Coil springs do not have much ability to resist lateral movement. However, when coil springs are used on the drive wheels, the suspension usually has special bars to prevent lateral movement.

Linear-Rate Coil Springs. Coil springs are classified into two general categories: linear rate and variable rate. **Linear-rate coil springs** have equal spacing between the coils and one basic shape with a consistent wire diameter. When the load is increased on a linear-rate spring, the spring compresses and the coils twist or deflect. As the load is removed from the spring, the coils unwind, or flex, back to their original position. The spring rate is the load required to deflect the spring 1 inch. Linear-rate coil springs have a constant spring rate, regardless of the load. For example, if 200 pounds deflect the spring 1 inch, 400 pounds deflect the spring 2 inches. The spring rate on linear springs is usually calculated between 20 and 60 percent of the total spring deflection.

Variable-Rate Coil Springs. Variable-rate coil springs have a variety of wire sizes and shapes. The most common variable-rate coil springs have a consistent wire diameter with a cylindrical shape and unequally spaced coils (Figure 6-1).

Inactive coils are positioned at each end of a coil spring.

Transitional coils are positioned between the inactive coils and the active coils in the center of the spring.

The **active coils** are located in the center of a coil spring.

The **inactive coils** at the end of the spring introduce force into the spring when the wheel strikes a road irregularity. When the **transitional coils** are compressed to their point of maximum load-carrying capacity, these coils become inactive. The **active coils** operate during the complete range of spring loading. When a stationary load is applied to a variable-rate coil spring, the inactive coils theoretically support the load. If the load is increased, the transitional coils support the load until they reach maximum load-carrying capacity, and the active coils carry the remaining overload. This spring action provides automatic load adjustment while maintaining vehicle height.

Some variable-rate coil springs have a tapered wire in which the active coils have the larger diameter, and the inactive coils have the smaller diameter. Other variable-rate spring designs include truncated cone, double cone, and barrel shape. A variable-rate spring does not have a standard spring rate. This type of spring has an average spring rate based on the load at a predetermined spring deflection. *It is impossible to compare variable spring rates and linear spring rates because of this difference in spring rates.* Variable-rate coil springs usually have more load-carrying capacity than linear-rate springs in the same application.

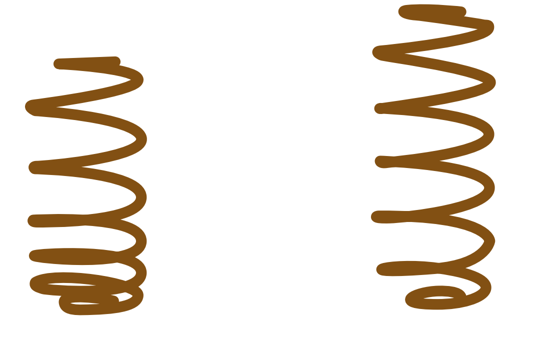

FIGURE 6-1 **Variable rate coil springs have consistent wire diameter and unequally spaced coils.**

Light-Weight Coil Springs

A few sports cars are presently equipped with titanium coil springs. This type of coil spring reduces the weight on the front springs by 39 percent and 28 percent on the rear springs compared to steel coil springs. Decreasing the weight of the coil springs reduces the **unsprung weight** and improves ride control. The unsprung vehicle weight tends to force the wheel downward during rebound wheel travel. Higher unsprung weight drives the wheel downward with greater force and increases the impact force between the tire and the road surface, resulting in a harsh ride. To compensate for the high unsprung weight, the shock absorber damping rate must be increased. This suspension design reduces ride quality. When the unsprung weight is reduced, the wheel is forced downward with less force, reducing the shock absorber damping rate and improving ride quality.

Unsprung weight is the vehicle weight that is not supported by the coil springs, and **sprung weight** is the vehicle weight that is supported by the coil springs.

Heavy-Duty Coil Springs. Heavy-duty coil springs are designed to carry 3 to 5 percent greater loads than regular-duty coil springs. The wire diameter may be up to 0.100 inch greater in a heavy-duty spring than in a regular-duty coil spring. This larger-diameter wire increases the load-carrying capacity of the spring. The free height of a heavy-duty coil spring is shorter than a regular-duty coil spring for the same application (Figure 6-2).

Selecting Replacement Springs. When replacement coil springs are required, the technician must select the correct spring. The original part number is usually on a tag wrapped around one of the coils. However, this tag may have fallen off if the spring has been in service for very long. Some aftermarket suppliers stamp the part number on the end of the coil spring. If the original part number is available, the replacement springs may be ordered with the same part number. Most vehicle manufacturers recommend that both front or rear springs be replaced at the same time. The replacement springs must have the same type of ends as the springs in the vehicle. Coil spring ends may be square tapered, square untapered, or tangential (Figure 6-3).

Full-wire open-end springs have the ends cut straight off, and sometimes these ends are flattened, squared, or ground to a D-shape. **Taper-wire closed-end springs** are ground to a taper and wound to ensure squareness. **Pigtail spring ends** are wound to a smaller diameter. Springs are generally listed for front or rear suspensions.

Regular-duty coil springs are a close replacement for the original spring in the vehicle, and these springs may replace several different original equipment (OE) springs in the same vehicle. Linear-rate coil springs are usually found in regular-duty, heavy-duty, and sport suspension packages. Heavy-duty coil springs are required when the vehicle is carrying a continuous heavy load, such as trailer towing.

If a wheel moves upward in relation to the chassis, this action is referred to as jounce travel. Downward wheel movement is called rebound travel.

Variable-rate coil springs are generally used when automatic load leveling is required under increased loads. Variable-rate coil springs maintain the correct vehicle height under various loads and provide increased load-carrying capacity compared to heavy-duty coil springs. The technician must select the correct spring to meet the requirements of the vehicle and load conditions.

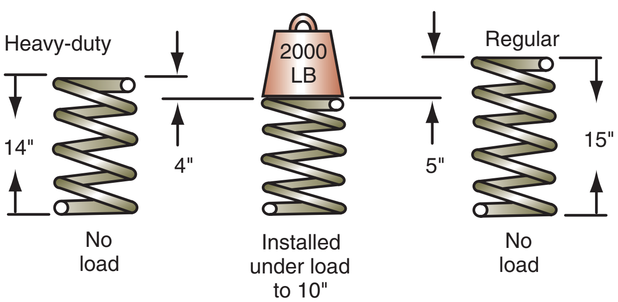

FIGURE 6-2 **Comparison of heavy-duty and regular-duty coil springs.**

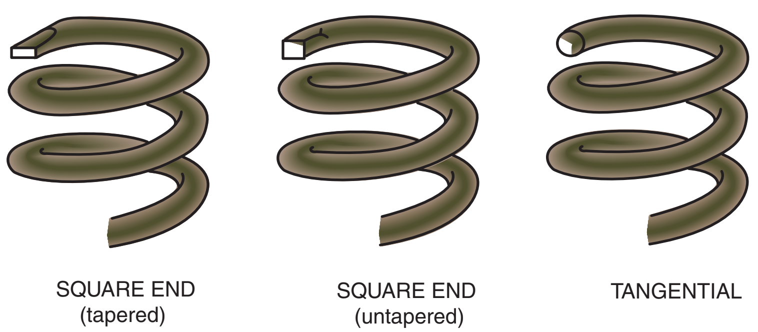

FIGURE 6-3 **Types of coil spring ends.**

WARNING: A very large amount of energy is stored in a compressed coil spring. Always follow the spring service procedures in the vehicle manufacturer's service manual to avoid personal injury.

WARNING: Never disconnect a suspension component that quickly releases the tension on a compressed coil spring. This action may cause personal injury.

Torsion Bars

In some front suspension systems, torsion bars replace the coil springs. During wheel jounce, the torsion bar twists. During wheel rebound, the torsion bar unwinds back to its original position. A torsion bar may be thought of as a straight, flattened coil spring. One end of the heat-treated alloy steel torsion bar is attached to the vehicle frame, and the opposite end is connected to the lower control arm. A few vehicles have the end of the torsion bars connected to the upper control arm. Some light-duty trucks and sport utility vehicles (SUVs) are presently equipped with longitudinal torsion bars in the front suspension (Figure 6-4). Transversely mounted torsion bars were used in some front suspensions on older cars.

Because the lower control arm moves up and down as the wheel strikes road irregularities, this control arm action twists the torsion bar. The bar's natural resistance to twisting causes it to return to its original position. During the manufacturing process, torsion bars are prestressed to provide fatigue strength. These bars are directional. Torsion bars are marked right or left, and they must be installed on the appropriate side of the vehicle. Left and right on a vehicle is always viewed from the driver's seat.

A torsion bar is capable of storing a higher maximum energy compared with a loaded coil or leaf spring. Shorter, thicker torsion bars have increased load-carrying capacity compared with longer, thinner bars. Since torsion bars require less space compared with coil or leaf springs, they are usually found on front suspensions. However, a few rear suspensions have torsion bars. Torsion bars have a riding height adjustment screw at the end where they are attached to the frame.

FIGURE 6-4 **Longitudinal torsion bar.**

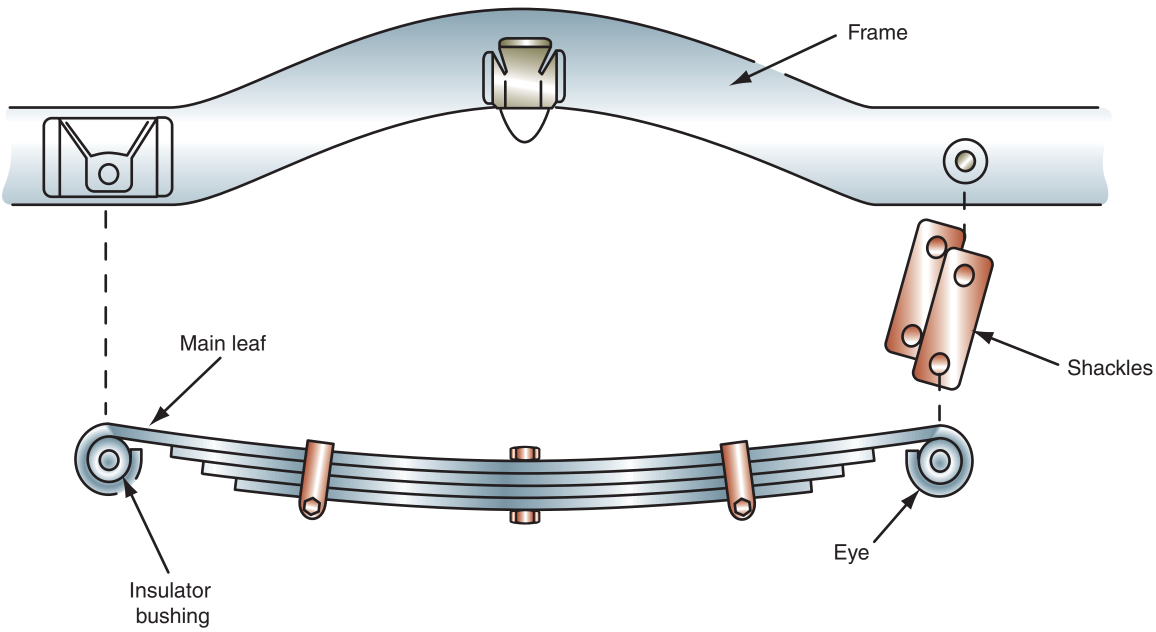

FIGURE 6-5 **Leaf spring design.**

Multiple-Leaf Springs

Leaf springs may be multiple-leaf or mono-leaf. **Multiple-leaf springs** have a series of flat steel leaves of varying lengths that are clamped together. A center bolt extends through all the leaves to maintain the leaf position in the spring. The upper leaf is called the main leaf, and this leaf has an eye on each end. An insulating bushing is pressed into each main leaf eye. The front bushing is attached to the frame, and the rear bushing is connected through a shackle to the frame. The shackle provides fore-and-aft movement as the spring compresses (Figure 6-5).

The main leaf is the longest leaf in the spring, and the other leaves get progressively shorter. Each spring leaf is curved in the manufacturing process. If this curve were doubled, it would form an ellipse. Therefore, leaf springs are referred to as semielliptical or quarter elliptical. Most leaf springs are semielliptical. The ellipse designation refers to how much of the ellipse the spring actually describes.

As a leaf spring compresses, it becomes progressively stiffer. When a leaf spring is compressed, the length of the leaves changes, and the leaves slide on each other. This sliding action could be a source of noise and friction. These noise and friction problems are reduced by interleaves, or spacers, made from zinc and plastic placed between the steel leaves. The head on the spring center bolt fits into an opening in the axle to position the axle properly and provide proper vehicle tracking. If the center bolt is broken, the axle position may shift and alter vehicle tracking and alignment. Leaf springs are usually mounted at right angles to the axle. They provide excellent resistance to lateral movement.

A Bit of History

The transverse leaf spring front and rear suspension is one of the oldest suspension systems in the automotive industry. It was used on Ford products from the early 1900s until 1948.

Mono-Leaf Springs

Some leaf springs contain a single steel leaf, and these springs may be referred to as **mono-leaf springs.** The single leaf is thicker in the center and becomes gradually thinner toward the outer ends. This design provides a variable spring rate for a smooth ride and adequate load-carrying capacity. Mono-leaf springs do not have a friction and noise problem as the spring compresses. Some cars, such as the Corvette and front-wheel-drive Oldsmobile Cutlass Supreme, use a fiberglass-reinforced plastic mono-leaf spring in place of a steel spring to reduce weight (Figure 6-6). The mono-leaf spring may be mounted longitudinally or transversely, and this type of spring may be used in front or rear suspensions.

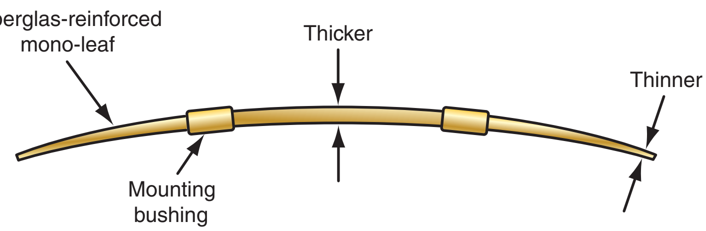

FIGURE 6-6 **Transversely mounted fiberglass mono-leaf spring.**

Older model Chevrolet Astro vans have longitudinally mounted fiberglass mono-leaf rear springs.

Ball Joints

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The ball joints act as pivot points that allow the front wheels and spindles, or knuckles, to turn between the upper and lower control arms. Compared with the earlier I-beam and kingpin-type front suspension systems, ball-joint suspension systems are much simpler. A front suspension with ball joints reduces the number of load-carrying bearing surfaces. Compared with an I-beam front suspension with kingpins, a front suspension with ball joints has these advantages:

1. Reduced space requirements
2. Reduced unsprung weight
3. Easier alignment
4. More dependable steering control
5. Improved safety
6. Improved tire life
7. Reduced steering effort
8. Improved ride quality
9. Simplified service—no kingpin reaming or honing
10. Simplified lubrication

WARNING: Worn ball joints may suddenly pull apart, resulting in loss of steering control and possibly a collision! Refer to the procedures in the Shop Manual Chapter 6 for measuring ball joint wear.

Load-Carrying Ball Joint

Ball joints may be grouped into two classifications, load carrying and non-load carrying. Ball joints may be manufactured with forged, stamped, cold-formed, or screw-machined housings. The coil spring is seated on the control arm to which the load-carrying ball joint is attached. For example, when the coil spring is mounted between the lower control arm and the chassis, the lower ball joint is a load-carrying joint (Figure 6-7). In a torsion bar suspension, the **load-carrying ball joint** is mounted on the control arm to which the torsion bar is attached. A load-carrying ball joint supports the vehicle weight.

In a load-carrying ball joint, the vehicle weight forces the ball stud into contact with the bearing surface in the joint. Load-carrying ball joints may be compression loaded or tension loaded. If the control arm is mounted above the lower end of the knuckle and rests on the knuckle, the ball joint is **compression loaded.** In this type of ball joint, the vehicle weight is pushing downward on the control arm. This weight is supported on the tire and wheel, which are attached to the steering knuckle. Since the ball joint is mounted between the control arm and the steering knuckle, the vehicle weight squeezes the ball joint together (Figure 6-8). In this type of ball-joint mounting, the ball joint is mounted in the lower control arm and the ball joint stud faces downward (Figure 6-9).

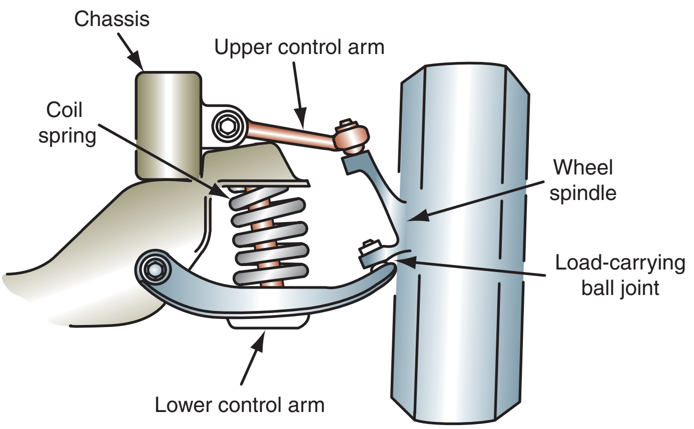

FIGURE 6-7 **Load-carrying ball joint mounted on the control arm on which the spring is seated.**

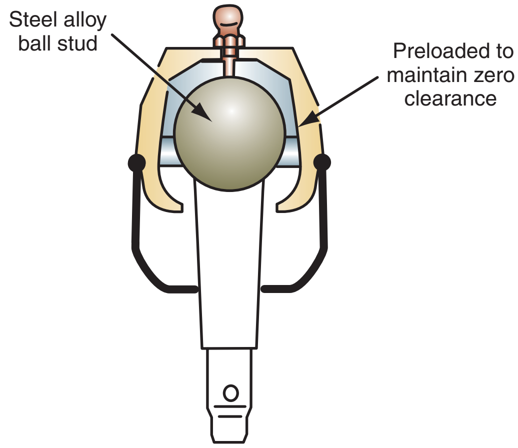

FIGURE 6-8 **Compression-loaded ball joint.**

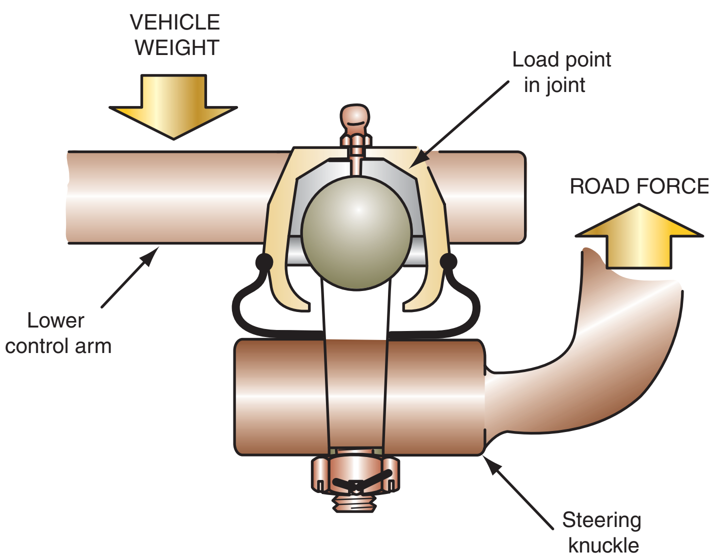

FIGURE 6-9 **Compression-loaded ball joint mounting.**

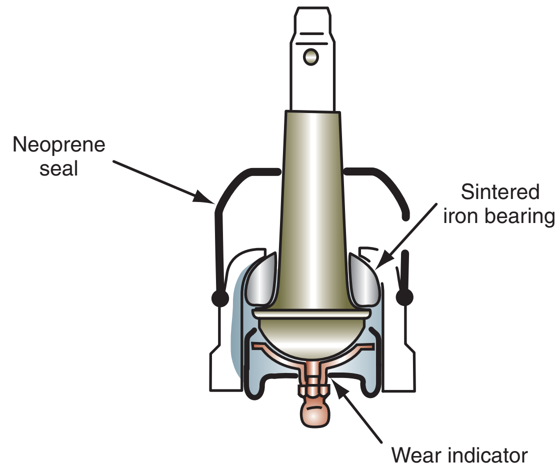

FIGURE 6-10 **Tension-loaded ball joint.**

When the lower control arm is positioned below the steering knuckle, the vehicle weight is pulling the ball joint away from the knuckle (Figure 6-10). This type of ball joint mounting is referred to as **tension loaded.** This type of ball joint is mounted in the lower control arm with the ball-joint stud facing upward into the knuckle (Figure 6-11).

Since the load-carrying ball joint supports the vehicle weight, this ball joint wears faster compared with a non-load-carrying ball joint. Many load-carrying ball joints have built-in **wear indicators.** These ball joints have an indicator on the grease nipple surface that recedes into the housing as the joint wears. If the ball joint is in good condition, the grease nipple shoulder extends a specified distance out of the housing. If the grease nipple shoulder is even with or inside the ball-joint housing, the ball joint is worn and replacement is necessary (Figure 6-12).

Most states have safety inspection procedures for testing ball joints and other safety-related components. These safety inspection procedures include specifications. Always follow the guidelines when performing safety inspections.

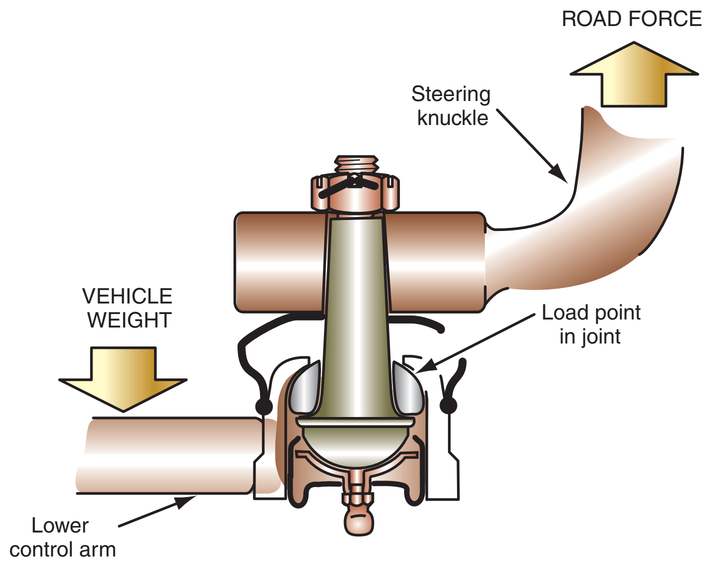

FIGURE 6-11 **Tension-loaded ball joint mounting.**

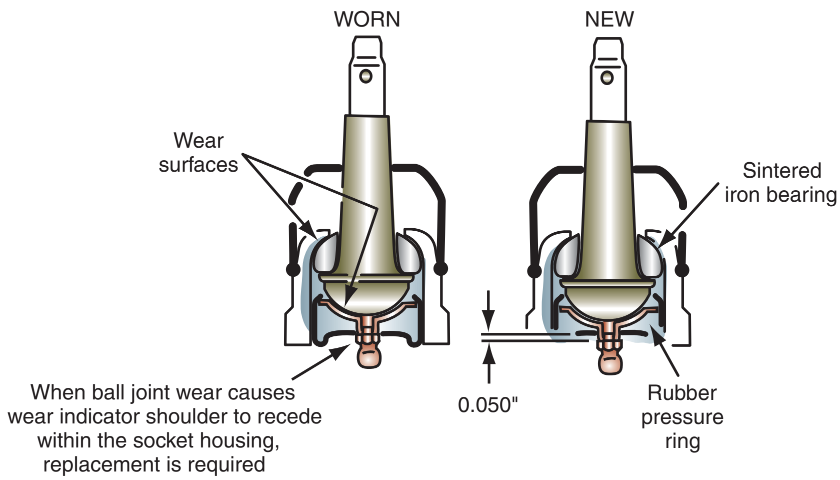

FIGURE 6-12 **Ball joint wear indicator.**

A **non-load-carrying ball joint** maintains knuckle position, but this ball joint does not support the vehicle weight.

Non-Load-Carrying Ball Joint

A **non-load-carrying ball joint** may be referred to as a stabilizing or follower ball joint. A non-load-carrying ball joint is designed with a preload, which provides damping action (Figure 6-13). This ball joint preload provides improved steering quality and vehicle stability.

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Low-Friction Ball Joints

Low-friction ball joints are standard equipment on many vehicles. Low-friction ball joints provide precise low-friction movement of the ball socket in the ball joint. Compared to conventional ball joints, two-thirds of the internal friction is eliminated in a low-friction ball joint. The smooth ball socket movement in a low-friction ball joint provides improved steering performance, better steering wheel return, and longer ball joint life. Low-friction ball joints have a highly polished ball socket surface surrounded by a high-strength polymer bearing (Figure 6-14).

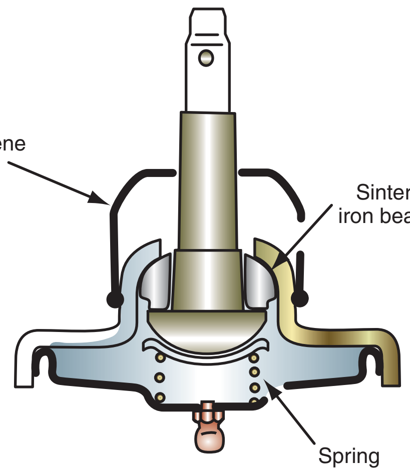

FIGURE 6-13 **Non-load-carrying ball joint.**

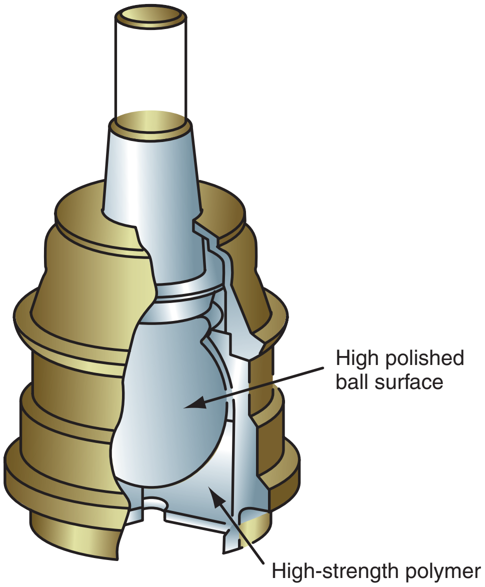

FIGURE 6-14 **Low-friction ball joint.**

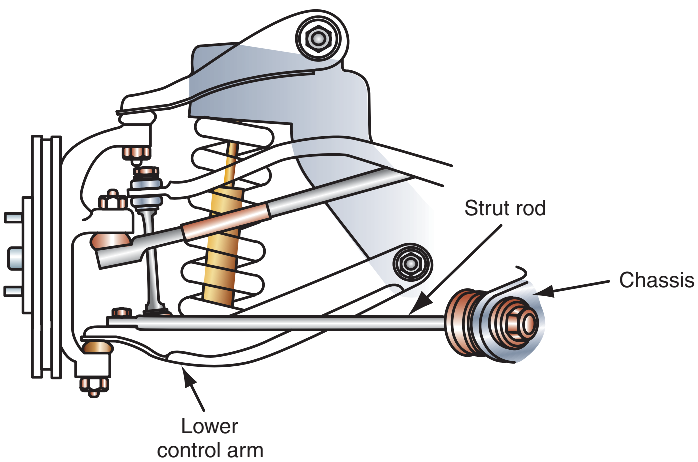

FIGURE 6-15 **Strut, or radius, rod and bushings.**

Strut Rod

On some front suspension systems, a strut rod is connected from the lower control arm to the chassis. The strut rod is bolted to the control arm, and a large rubber bushing surrounds the strut rod in the chassis opening. The outer end of the strut rod is threaded and steel washers are positioned on each side of the strut rod bushing. Two nuts tighten the strut rod into the bushing (Figure 6-15). The strut rod prevents fore-and-aft movement of the lower control arm. In some suspension systems, the position of the strut rod nuts provides proper front wheel adjustment.

Some strut rods are presently manufactured from tubular steel to reduce strut rod and unsprung weight.

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AUTHOR'S NOTE: It has been my experience that the most important item when diagnosing automotive problems is your knowledge of automotive systems and components. You must understand the operation of automotive systems and the individual components within these systems. Second, you must be familiar with the problems that certain worn, defective, or misadjusted components can cause. When

diagnosing an automotive problem, you must identify the exact problem, and then think of all the causes of the problem. When you are familiar with all the causes of the problem, you will know the system and component where diagnosis should begin. The cause of an automotive problem may not be in the system where the problem seems to appear. For example, a problem of steering pull during braking would usually be caused by a defect in the brake system. However, a worn front strut rod bushing may allow the front suspension on one side to move rearward during braking, which changes the front suspension alignment angles and causes steering pull when braking. Therefore, if you know that a worn radius arm bushing may cause steering pull when braking, you will inspect this component in the diagnosis as well.

Short-and-Long Arm Front Suspension Systems

Upper and Lower Control Arms

Many years ago, cars were equipped with I-beam front suspension systems designed with king pins and longitudinally mounted leaf springs. A few modern trucks are still equipped with this type of suspension. The king pins were retained in a vertical opening in the ends of the axle with a lock bolt. Upper and lower bushings in the steering knuckle pivoted on the upper and lower ends of the king pins (Figure 6-16). In this type of front suspension, if one front wheel moves upward or downward, some movement is transferred to the other end of the axle. This action tends to result in reduced ride quality, steering instability, and tire wear. As automotive technology evolved, the control arm front suspension system replaced the I-beam front suspension system. This type of front suspension system has coil springs with upper and lower control arms. Since wheel jounce or rebound movement of one front wheel does not directly affect the opposite front wheel, the control arm suspension is an independent system. Many rear-wheel-drive cars have control arm front suspension systems. Early front suspension systems had equal-length upper and lower control arms. On these early suspension systems, the bottom of the tire moved in and out with wheel jounce and rebound travel. This action constantly changed the tire tread width and caused tire scuffing and wear problems (Figure 6-17).

An independent suspension system is one in which wheel jounce or rebound travel of one wheel does not directly affect the movement of the opposite wheel.

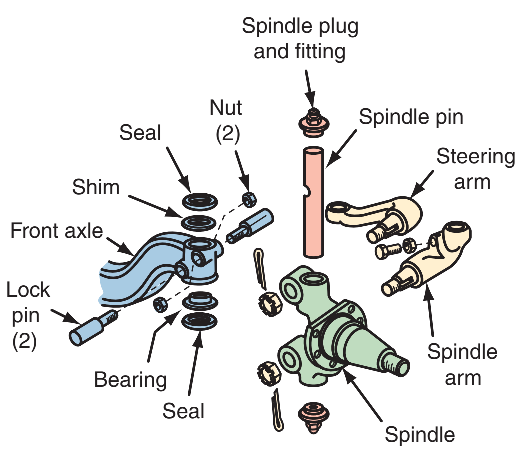

FIGURE 6-16 **I-beam front suspension with king pins.**

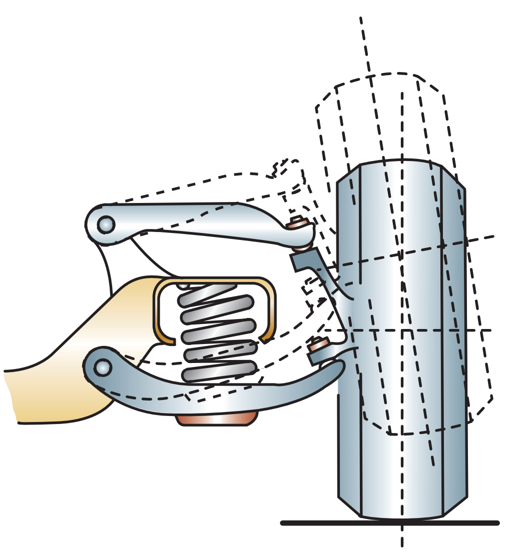

FIGURE 6-17 **Early front suspension system with equal length upper and lower control arms.**

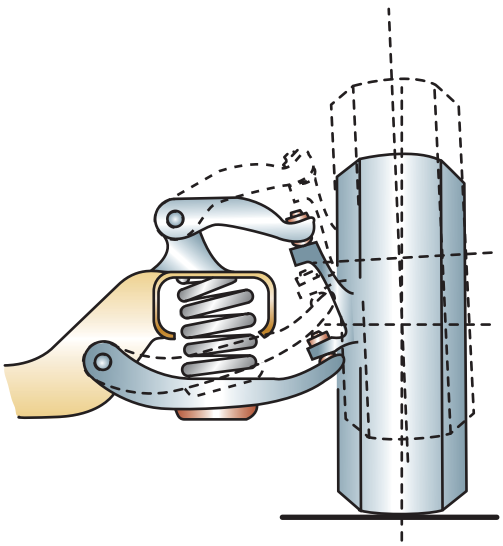

FIGURE 6-18 **Short-and-long arm front suspension system.**

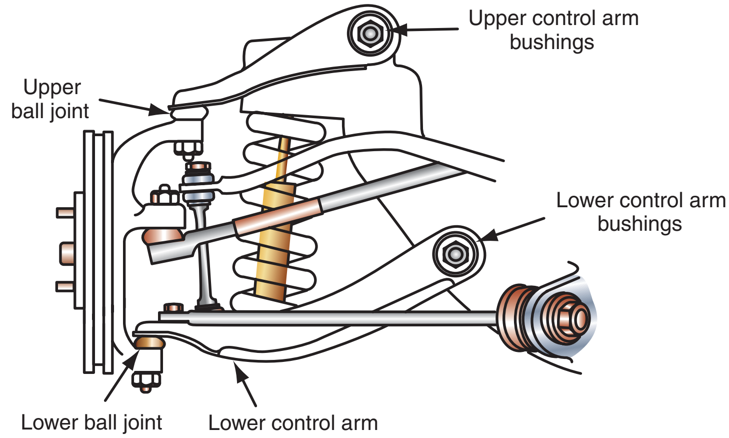

FIGURE 6-19 **Ball joints and complete short-and-long arm front suspension system.**

In later **short-and-long arm front suspension systems**, the upper control arm is shorter than the lower control arm. During wheel jounce and rebound travel in this suspension system, the upper control arm moves in a shorter arc than the lower control arm. This action moves the top of the tire in and out slightly, but the bottom of the tire remains in a more constant position (Figure 6-18). This short-and-long arm front suspension system provides reduced tire tread wear, improved ride quality, and better directional stability compared to I-beam suspension systems and suspension systems with equal-length upper and lower control arms.

The inner end of the lower control arm contains large rubber insulating bushings, and the ball joint is attached to the outer end of the control arm. The lower control arm is bolted to the front crossmember, and the attaching bolts are positioned in the center of the lower control arm bushings (Figure 6-19). The ball joint may be riveted, bolted, pressed, or threaded into the control arm. A spring seat is located in the lower control arm. An upper control arm shaft is bolted to the frame, and rubber insulators are located between this shaft and the control arm.

Some current vehicles have hydraulic control arm bushings on the front suspension. Hydraulic control arm bushings do a superior job of preventing road shocks and vibrations supplied to the control arms from reaching the body. This action improves ride quality.

Many current vehicles are equipped with aluminum upper and lower control arms and/or steering knuckles to reduce unsprung weight and improve ride quality. Any significant weight reduction also helps to improve fuel economy and vehicle performance and reduce CO_2 omissions. When servicing aluminum control arms, the use of the wrong tools may damage these components. Always use the tools specified by the vehicle manufacturer.

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On some short-and-long arm front suspension systems, the coil spring is positioned between the upper control arm and the chassis (Figure 6-20). In these suspension systems, the upper ball joint is compression loaded.

Steering Knuckle

The upper and lower ball joint studs extend through openings in the steering knuckle. Nuts are threaded onto the ball joint studs to retain the ball joints in the knuckle, and the nuts are secured with cotter pins. The wheel hub and bearings are positioned on the steering knuckle extension, and the wheel assembly is bolted to the wheel hub. When the steering wheel is turned, the steering gear and linkage turn the steering knuckle. During this turning action,

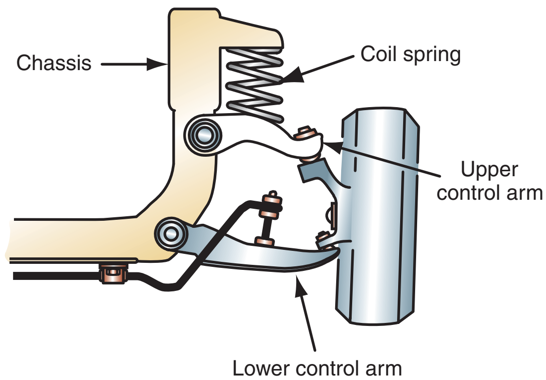

FIGURE 6-20 **Short-and-long arm front suspension with the coil spring between the upper control arm and the chassis.**

the steering knuckle pivots on the upper and lower ball joints. The upper and lower control arms must be positioned properly to provide correct tracking and wheelbase between the front and rear wheels. The control arm bushings must be in satisfactory condition to position the control arms properly.

Coil Spring and Shock Absorber

The coil spring is positioned between the lower control arm and the spring seat in the frame. A spring seat is located in the lower control arm, and an insulator is positioned between the top of the coil spring and the spring seat in the frame. The shock absorber is mounted in the center of the coil spring, and the lower shock absorber bushing is bolted to the lower control arm. The top of the shock absorber extends through an opening in the frame above the upper spring seat. Washers, grommets, and a nut retain the top of the shock absorber to the frame. Side roll of the front suspension is controlled by a steel stabilizer bar, which is mounted to the lower control arms and the frame with rubber bushings.

On some later model short-and-long arm front suspension systems, the lower end of the coil spring is mounted on a seat attached to the shock absorber. A rubber bushing containing a metal bar is installed in the lower end of the shock absorber. This bushing is bolted to the lower control arm (Figures 6-21 and 6-22). The upper end of the coil spring is seated on

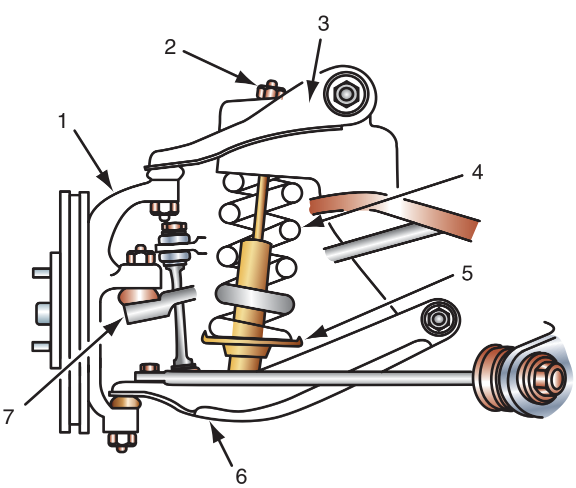

FIGURE 6-21 **Short-and-long arm front suspension system with coil spring mounted on the shock absorber.**

ITEM	DESCRIPTION
1	Steering knuckle
2	Nut, shock absorber upper mount
3	Upper control arm
4	Coil spring
5	Coil spring seat
6	Lower control arm
7	Tie-rod end

FIGURE 6-22 **Component identification in short-and-long arm suspension with the coil spring mounted on the shock absorber.**

an upper shock absorber mount. The rod in the center of the shock absorber extends through this mount, and a nut on the threaded end of the shock absorber rod retains the mount on the shock absorber. Bolts in the top of the upper shock absorber mount extend through the upper control arm.

The upper control arm is mounted high in the suspension system, and the upper end of the knuckle has a "goose neck" shape. The lower control arm is made from stamped steel to reduce weight. The rear lower control arm bushing is mounted vertically and carries only fore-and-aft loads. This mounting allows the use of a softer rear bushing in the lower control arm. The horizontal front lower control arm bushing and the lower shock absorber mounting are aligned with the wheel center. This provides a direct path for lateral cornering loads. This design allows the use of a hard front lower control arm bushing.

When servicing this suspension system, a special spring compressing tool must be used to compress all the spring tension before loosening the nut on top of the shock absorber rod (Figures 6-23 and 6-24). After this nut is removed, the compressing tool is operated to gradually release the spring tension, and then the upper mount may be removed. (Refer to Chapter 5 in the Shop Manual for strut and coil spring service.)

In the short-and-long arm front suspension system on the Trailblazer SUV, the coil spring is mounted over the shock absorber; the coil spring tension is applied against the upper mount and the lower spring seat on the shock absorber (Figure 6-25). A special yoke attaches to the lower end of the shock absorber, and the lower end of this yoke pivots on a bolt in the lower control arm (Figure 6-26). This type of suspension system provides a more

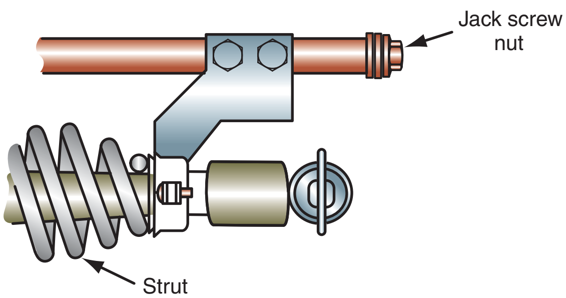

FIGURE 6-23 **Lower end of spring compressing tool.**

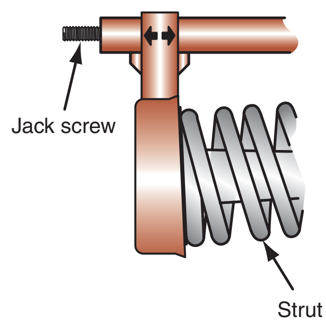

FIGURE 6-24 **Upper end of spring compressing tool.**

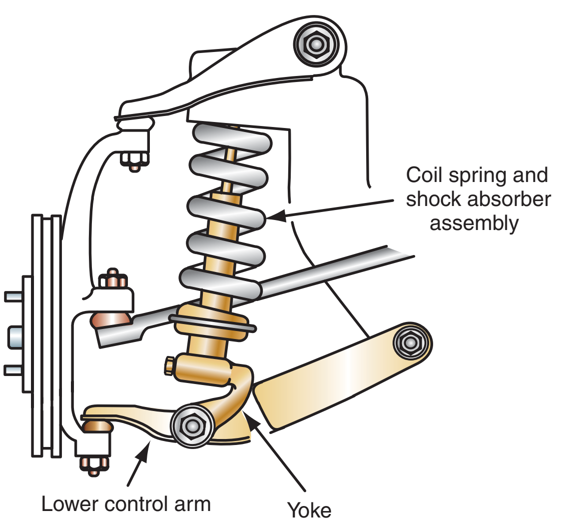

FIGURE 6-25 **Short-and-long arm front suspension with yoke-type shock absorber mounting.**

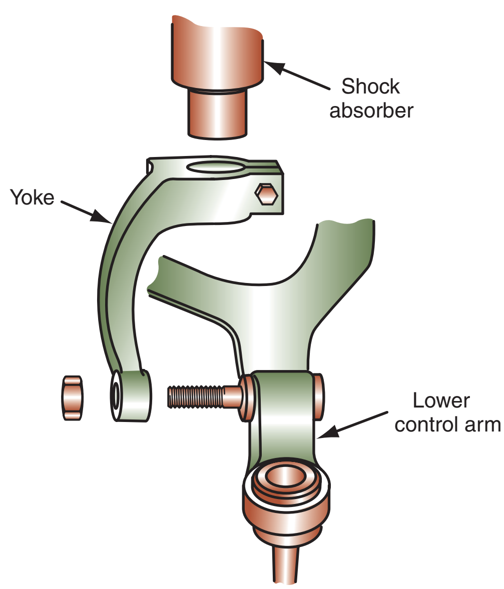

FIGURE 6-26 **Shock absorber with yoke attachment to lower control arm.**

CAUTION:
Never loosen the nut on top of the shock absorber rod until a coil spring compressing tool is used to compress all the spring tension. Failure to follow this procedure may cause the spring tension to suddenly release, resulting in personal injury.

positive shock absorber and spring mounting because the rubber bushing-type mounting between the shock absorber and the lower control arm is not required. The steering knuckle pivots on the upper and lower ball joints in the control arms. Therefore, the shock absorber and coil spring do not have to turn when the knuckle turns, which allows the use of a more rigid upper spring mount. This suspension design provides improved vehicle handling and ride characteristics.

Improved Designs in Short-and-Long Arm Front Suspension Systems

Some vehicles now have a reverse-L front suspension system. In these suspension systems, the rear attachment point on the lower control arm extends rearward and attaches to the engine cradle at a point farther toward the rear of the vehicle (Figure 6-27). The lower control arm has an L-shaped design. A firm bushing is installed at the location where the shorter forward leg of the lower control arm attaches to the cradle to control lateral control arm movement and quicken steering response. A more compliant bushing is installed between the longer rear leg and the rear attachment point to absorb the impact of longitudinal forces caused by road irregularities. This type of suspension separates the control of suspension loads into fore-and-aft control and side-to-side control to improve ride and steering quality.

Other modern short-and-long arm front suspension systems have high upper control arms that place the upper ball joints above the tires to provide suspension articulation that helps to keep the tire perpendicular to the road surface while cornering (Figure 6-28). This type of front suspension system has a lateral link and a tension strut to position the lower end of the knuckle and the lower ball joint rather than a lower control arm. The lateral link extends slightly forward from the lower ball joint to an attachment point on the chassis. Bushings are mounted in both ends of the lateral link. The tension strut extends rearward from the lower ball joint to the attachment location on the chassis. This type of front suspension also separates the control of suspension loads to improve ride quality and steering control. This type of front suspension may be called a four-link suspension system.

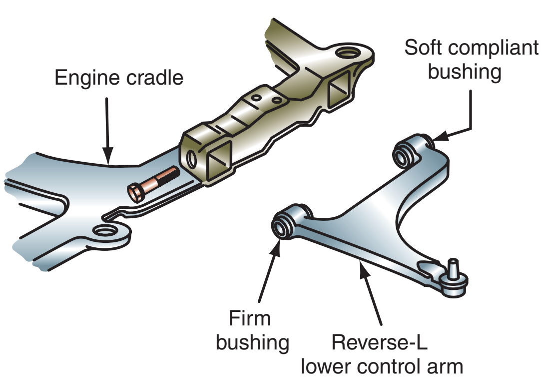

FIGURE 6-27 **Reverse-L front suspension system with firm, front lower control arm bushing and more compliant rear, lower control arm bushing.**

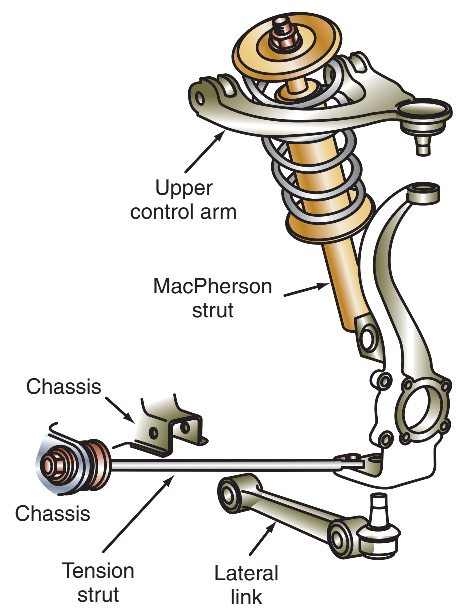

FIGURE 6-28 **Front suspension system with lateral link and tension strut in place of lower control arm.**

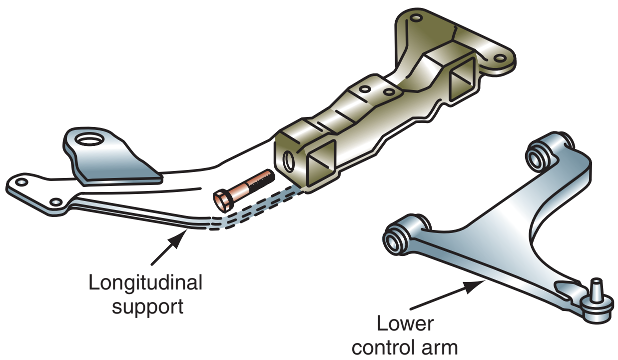

FIGURE 6-29 **Lower control arm and support**

MacPherson Strut Front Suspension System Design

Lower Control Arms and Support

When smaller front-wheel-drive cars became popular, most of these cars had **MacPherson strut front suspension systems.** In these suspension systems, the lower end of the strut is bolted to the top of the steering knuckle, and the lower end of the knuckle is attached to the ball joint in the lower control arm. An upper strut mount connects the top of the strut to the chassis. An upper control arm is not required in this type of suspension system, because the strut supports the top of the steering knuckle. Since the upper control arm is not required in these suspension systems, they are more compact and therefore very suitable for smaller cars.

On some MacPherson strut front suspension systems, a steel support is positioned longitudinally on each side of the front suspension. These supports are bolted to the unitized body. The inner ends of the lower control arms contain large insulating bushings with a bolt opening in the bushing center. The control arm retaining bolts extend through the center of these bushings and openings in the support (Figure 6-29).

Road irregularities cause the tire and wheel to move up and down vertically, and the lower control arm bushings pivot on the mounting bolts during this movement. When the vehicle is driven over road irregularities, vibration and noise are applied to the tire and wheel. The control arm bushings help prevent the transfer of this noise and vibration to the support, the unitized body, and the passenger compartment. Proper location of the support and lower control arm is important to provide correct vehicle tracking. The supports also carry the engine and transaxle weight. Large rubber mounts are positioned between the supports and the engine and transaxle. These mounts absorb engine vibration.

A Bit of History

Rear-wheel-drive cars usually have short-and-long arm or torsion bar front suspension systems. Since space and weight are important factors on today's smaller, more efficient front-wheel-drive cars, the lighter, more compact MacPherson strut front suspension is used on most of these cars.

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Stabilizer Bar

The **stabilizer bar** is attached to the chassis and interconnects the lower control arms. Rubber insulating bushings are used at all stabilizer bar mounting positions. Some stabilizer bars are attached to the underside of the front crossmember, and the outer ends of the stabilizer bar are connected to the lower side of the front control arms (Figure 6-30). This type of torsion bar may be called "direct contact" because the outer ends of the bar are in direct contact with the lower control arms. Other stabilizer bars are attached to the upper side of the front longitudinal supports, and links are connected between the outer ends of the bar and the upper side of the front control arms (Figure 6-31). On some MacPherson strut front suspension systems, the stabilizer bars are attached to the upper side of the front subframe and the outer ends of the bar are linked to the front struts (Figure 6-32). Stabilizer bars with links between the outer ends of the bar and the suspension components may be called "indirect contact." Large rubber bushings with steel mounting caps

A stabilizer bar may be called a sway bar.

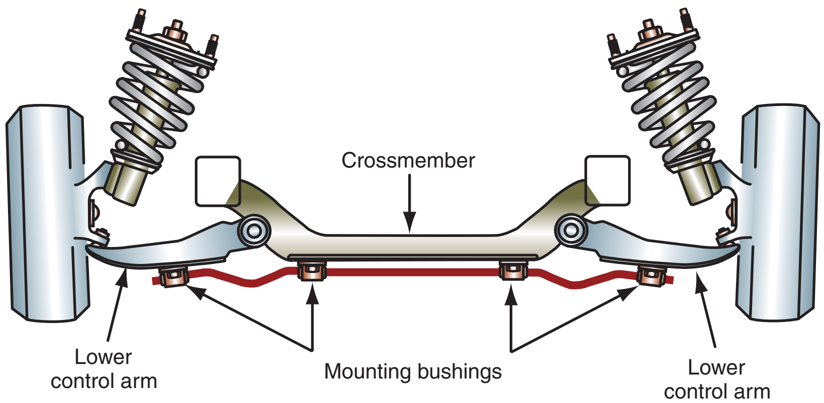

FIGURE 6-30 **Stabilizer bar with mounting bushings.**

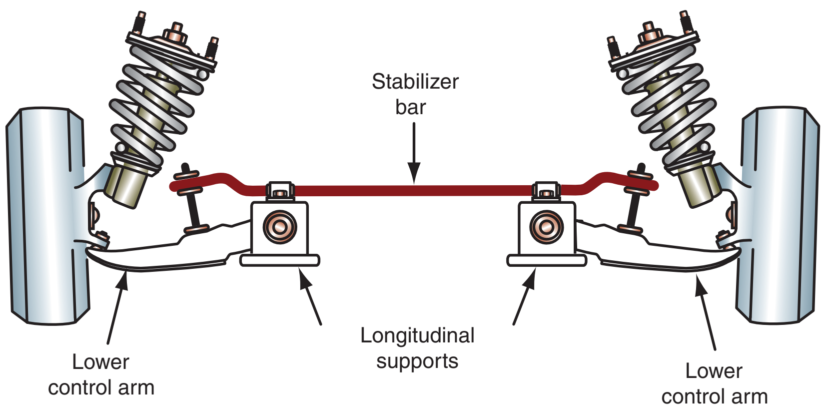

FIGURE 6-31 **Stabilizer bar connected between the two lower control arms.**

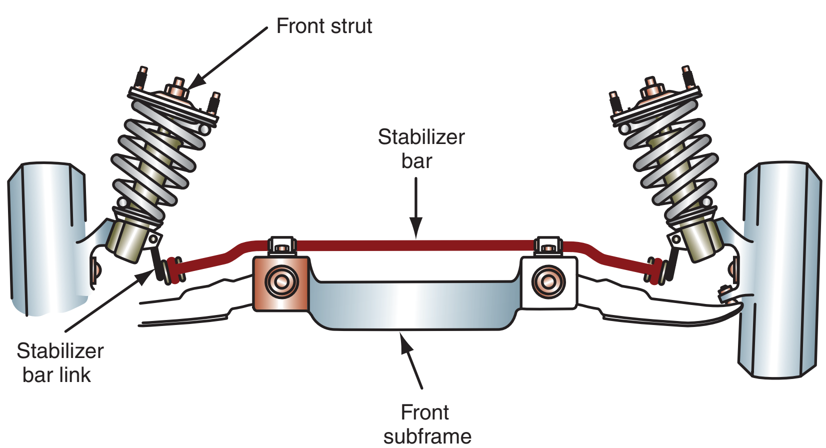

FIGURE 6-32 **Stabilizer bar connected to the front struts.**

attach the stabilizer bar to the chasis. The linkages at the outer ends of the stabilizer bar are connected to the control arms or struts with retaining bolts, small rubber bushings, steel washers, and sleeves.

The outer ends of the stabilizer bar move up and down with the control arm movement. When jounce or rebound wheel movement occurs, the stabilizer bar transmits part of this movement to the opposite front wheel to reduce and stabilize body roll. The rubber stabilizer bar mounting and linkage bushings prevent noise.

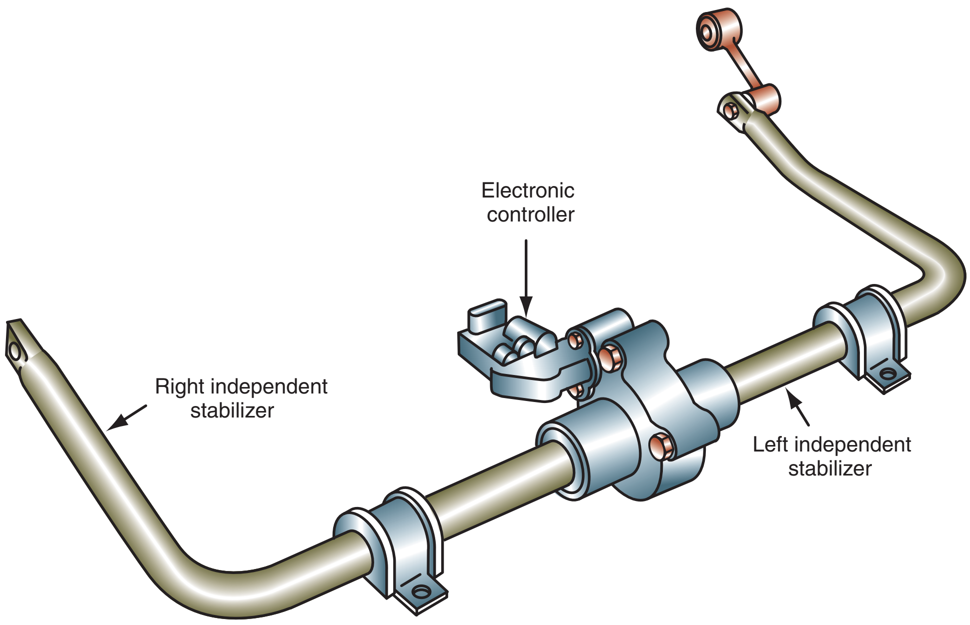

FIGURE 6-33 **Electronically controlled stabilizer bar.**

Some current vehicles have front and rear stabilizer bars with flat areas on the bars in the bushing contact areas. The bushings used with these bars have oval openings in the center of the bushing to match the flat areas on the bars. This stabilizer bar design reduces body roll while cornering or driving on irregular road surfaces, because more force is required to twist the stabilizer bar. Some vehicles are now equipped with aluminum stabilizer bars to reduce unsprung weight. Hollow stabilizer bars are used on some current vehicles for weight reduction.

In some suspension systems links are connected between the ends of the stabilizer bar and a bracket on the strut (Figure 6-32). An aftermarket electronically controlled stabilizer bar is available for off-road vehicle operation (Figure 6-33). In this type of stabilizer bar system the driver may press a switch in the instrument panel, and the electronic control disconnects one side of the stabilizer bar from the opposite side, thus making this component ineffective. When the stabilizer bar is disconnected electronically, full vertical wheel travel is allowed on rough terrain. The driver can press the control switch again to return the stabilizer bar to normal operation for stabilized control of body roll during on-road operation.

Lower Ball Joint

The lower ball joint is attached to the outer end of the lower control arm. Methods used to attach the ball joint to the control arm include bolting, riveting, pressing, and threading. A threaded stud extends from the top of the lower ball joint. This stud fits snugly into a hole in the bottom of the steering knuckle. When the ball joint stud is installed in the steering knuckle opening, a nut and cotter pin retain the ball joint (Figure 6-34).

Steering Knuckle and Bearing Assembly

The front wheel bearing assembly is bolted to the outer end of the steering knuckle, and the brake rotor and wheel rim are retained on the studs in the wheel bearing assembly. This front wheel bearing assembly is a complete, non-serviceable, sealed unit. The front drive shaft is splined into the center of the wheel bearing hub. Thus, drive axle torque is applied to the front wheel. A tie-rod end connects the steering linkage from the steering gear to the steering knuckle. The top end of the steering knuckle is bolted to the lower end of the strut (Figure 6-35).

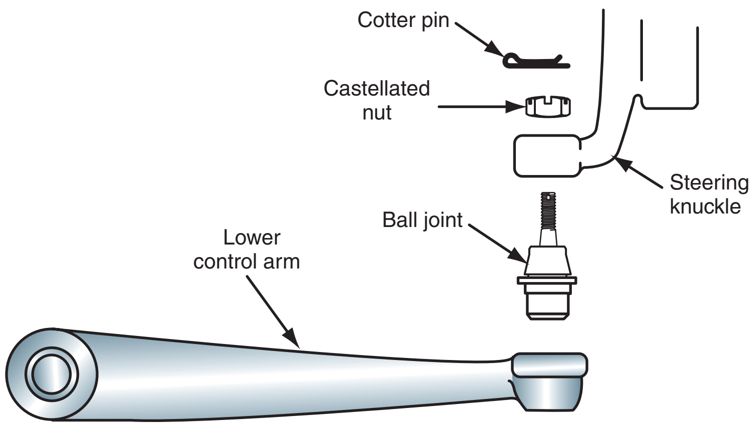

FIGURE 6-34 **Lower ball joint.**

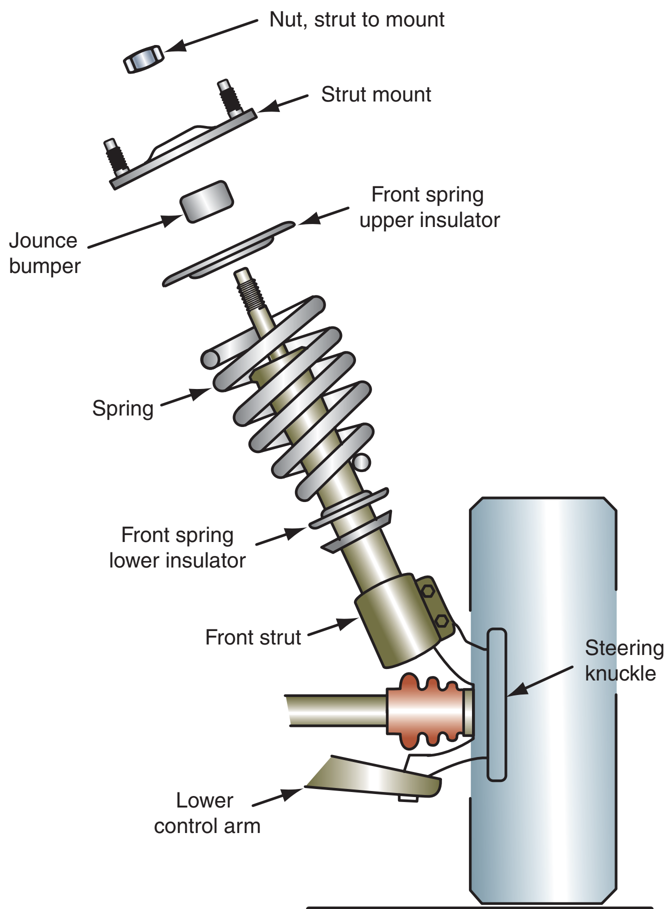

FIGURE 6-35 **Complete MacPherson strut front suspension system.**

Many steering knuckles are manufactured from metal, but some current vehicles have aluminum steering knuckles to reduce vehicle weight and unsprung weight. Reducing unsprung weight improves ride quality and vehicle performance and reduces fuel consumption and CO_2 emissions.

Strut and Coil Spring Assembly

The strut is the shock absorber in the front suspension. The lower spring seat is attached near the center area of the strut. An insulator is located between the lower spring seat and the bottom of the coil spring. An upper strut mount is retained on top of the strut with a nut

threaded onto the upper end of the strut rod. The upper strut mount contains a bearing and upper spring seat, and an insulator is positioned between the top of the coil spring and the seat. The upper and lower insulators help prevent the transfer of noise and vibration from the spring to the strut and body.

A bumper is located on the upper end of the strut rod. This bumper reduces harshness while driving on severe road irregularities. During upward wheel movement, the bumper strikes the upper spring seat before the coils in the spring hit each other. Therefore, this bumper reduces harshness when the wheel and suspension move fully upward. The spring tension is applied against the upper and lower spring seats and insulators. However, the nut on top of the upper mount holds the spring in the compressed position between the upper and lower spring seats. When the steering wheel is turned, the steering linkage turns the steering knuckles to the right or left. During this front wheel turning action, the strut-and-spring assembly pivots on the lower ball joint and the upper strut mount bearing.

All the suspension-to-chassis mounting devices such as the lower control arm bushings and the upper strut mount must be positioned properly and be in satisfactory condition to provide correct vehicle tracking and the same wheelbase on both sides of the vehicle.

The purpose of the main components in a MacPherson strut front suspension system may be summarized as follows:

1. Lower control arm—controls lateral (side-to-side) movement of each front wheel.
2. Stabilizer bar—reduces body roll when a front wheel strikes a road irregularity.
3. Coil springs—allow proper setting of suspension ride heights and control suspension travel during driving maneuvers.
4. Shock absorber struts—provide necessary suspension damping and limit downward wheel movement with an internal rebound stop and upward wheel movement with an external jounce bouncer.
5. Strut upper mount—insulates the strut and spring from the body and provides a bearing pivot for the strut-and-spring assembly.
6. Ball joint—connects the outer end of the lower control arm to the steering knuckle and acts as a pivot for the strut, spring, and knuckle assembly.

MacPherson strut front suspension systems are all similar in design, but some vehicle manufacturers provide unique differences in their suspension systems. For example, the MacPherson strut front suspension system on the new Jaguar X-type car has two significant differences: an arm extends several inches inward from the top of the steering knuckle and the lower end of the strut is attached to the inner end of this arm (Figure 6-36). The upper strut mount contains a specially designed bearing that allows the strut-and-spring assembly

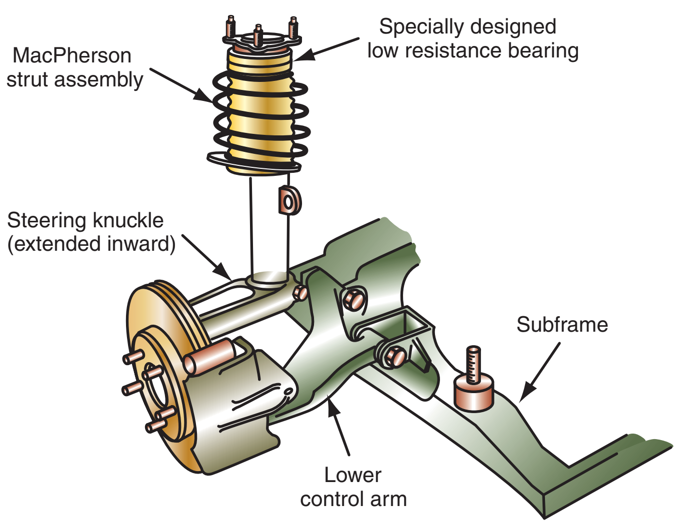

FIGURE 6-36 **MacPherson strut front suspension system on Jaguar X-type car.**

to rotate freely regardless of the forces supplied to the front suspension. This upper strut mount design reduces friction within the struts and provides very smooth steering action.

Modified MacPherson Strut Suspension

A modified MacPherson strut front suspension is used on some older vehicles. This type of suspension has MacPherson struts with coil springs positioned between the lower control arms and the frame (Figure 6-37). The struts in these systems may be gas-filled or oil-filled.

High-Performance Front Suspension Systems

Multilink Front Suspension System

High-performance suspension systems are usually installed on sports cars. In these cars, the driver expects improved steering quality, especially when driving and cornering at higher speeds.

The **multilink front suspension** may be referred to as a double wishbone suspension because of the link design. It has upper and lower links, and a third link connects the upper link to the top of the knuckle through a bearing.

In a **multilink front suspension**, a short upper link is attached to the chassis with a bracket, and the outer end of this upper link is connected to a third link. Large rubber insulating bushings are mounted in each end of the upper link. The lower end of the third link is connected through a heavy pivot bearing to the steering knuckle (Figure 6-38). The lower link is similar to the conventional lower control arm. A rubber insulating bushing connects the inner end of the lower link to the front crossmember, and a ball joint is connected from the outer end of the lower link to the steering knuckle. In the multilink suspension system, the ball joint axis extends through the lower ball joint and upper pivot bearing, but the ball joint axis is independent from the upper and third links. The extra links in a multilink suspension system maintain precise wheel position during cornering to provide excellent directional stability and steering control while minimizing tire wear.

The shock absorbers are connected from the lower end of the third link to the fender reinforcement. A coil spring seat is attached to the lower end of the shock absorber, and the upper spring seat is located on the upper shock absorber mounting insulator (Figure 6-39). Since the steering knuckle pivots on the lower ball joint and the upper pivot bearing, the coil spring and shock absorber do not rotate with the knuckle as they do in a MacPherson strut suspension. Tension or strut rods are connected from the lower links

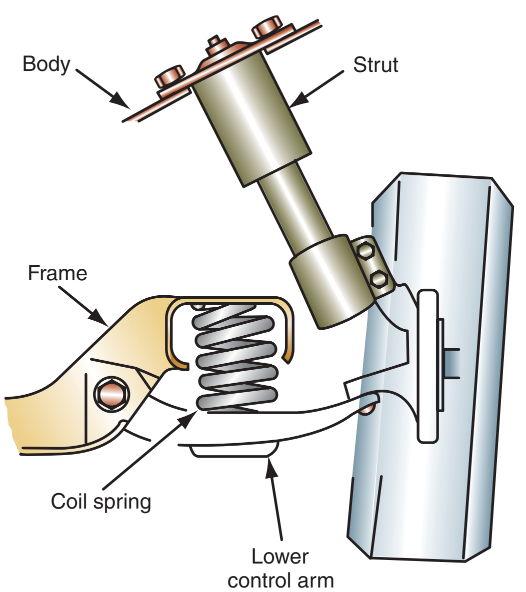

FIGURE 6-37 **Modified MacPherson strut front suspension system.**

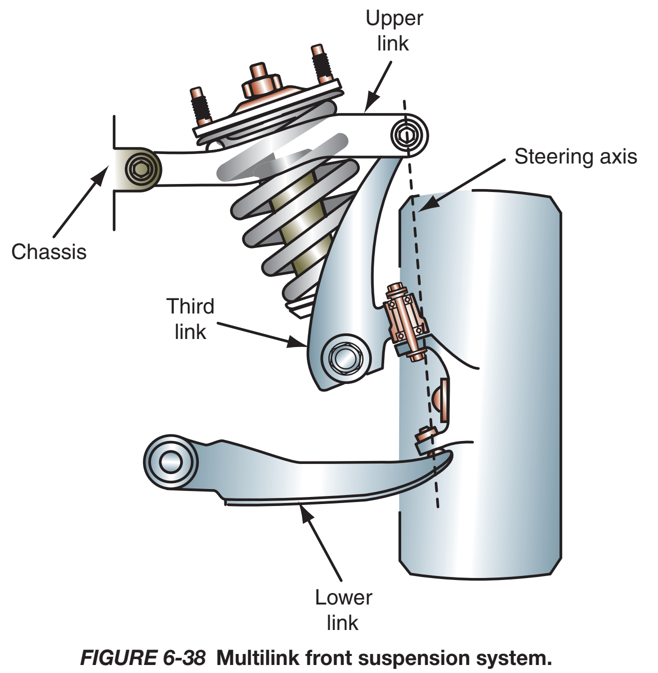

FIGURE 6-38 **Multilink front suspension system.**

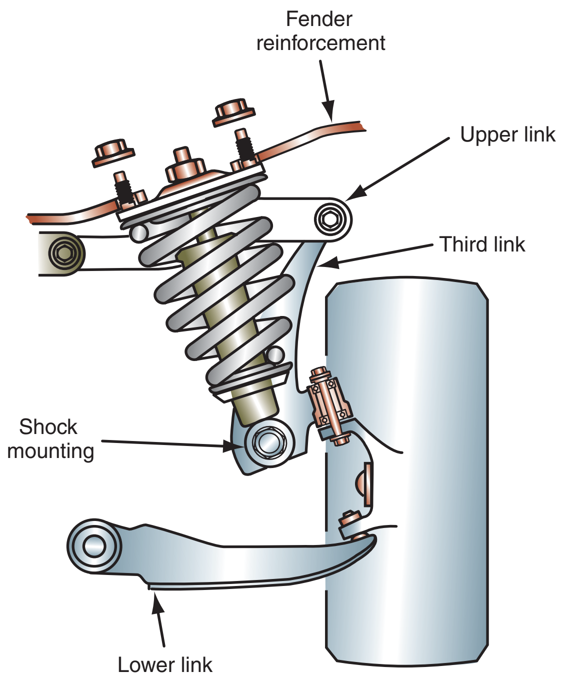

FIGURE 6-39 **Complete multilink suspension system.**

to tension rod brackets attached to the chassis. A stabilizer bar is mounted on rubber insulating bushings in the tension rod brackets, and the outer ends of this bar are attached to the third link.

Double Wishbone Front Suspension System

Double wishbone suspension systems provide increased suspension rigidity and maintain precise wheel position under all driving conditions to supply improved directional stability and steering control. In the double wishbone front suspension system, the upper and lower control arms are manufactured from lightweight, high-strength aluminum alloys designed for maximum strength and rigidity. These lighter control arms decrease the unsprung weight of the vehicle, which improves traction and ride quality. Since the upper and lower control arms have a wishbone shape, the term “double wishbone” is used for this type of suspension. Suspension rigidity is also increased by positioning the ball joints and steering knuckle inside the wheel profile (Figure 6-40). On each side of the car, the front suspension is attached to the chassis by a cast aluminum subframe. This design also reduces vehicle weight. The double wishbones are attached to the chassis at the most efficient locations to maintain precise wheel position and provide improved ride quality.

The front ends of the upper and lower control arms are attached to a compliance pivot assembly. Bushings are mounted in the front ends of the upper and lower control arms, and these bushings are bolted to the compliance pivot (Figure 6-41). When one of the front wheels is subjected to rearward force by hard braking or a road irregularity, the coil spring is compressed and the ride height is lowered. This rearward force on the front wheel twists the compliance pivot, allowing both control arms to pivot slightly. Under this condition, the upper and lower control arm movement allows the front wheel to move rearward a small amount, and this wheel movement absorbs energy to significantly improve ride quality (Figure 6-42). During this upper and lower control arm movement, track width and wheel geometry changes are minimal and do not affect steering control. While cornering, the compliance pivot does not move, and lateral suspension stiffness is maintained to supply excellent steering control.

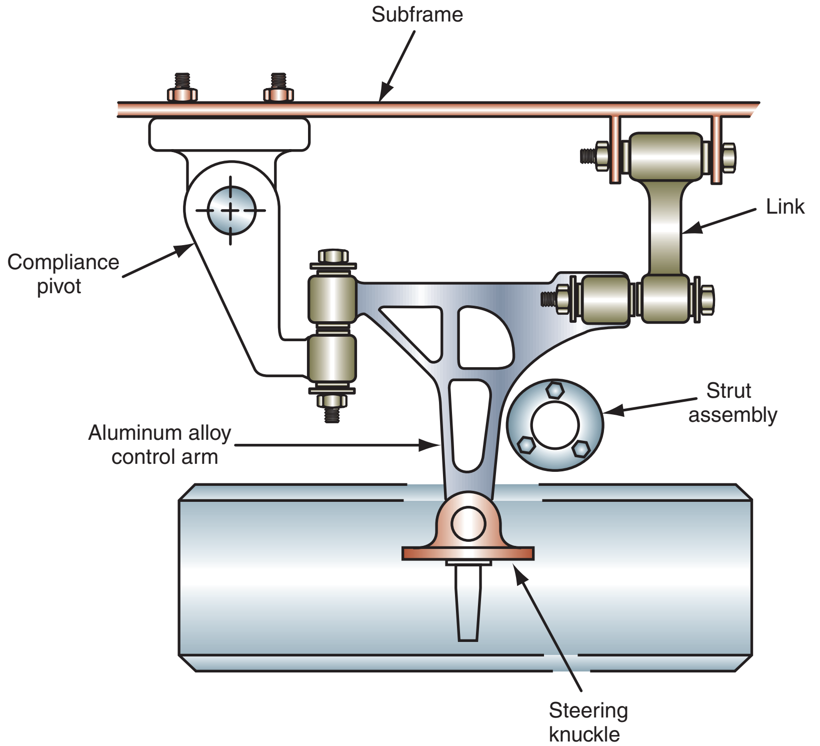

FIGURE 6-40 **Double wishbone front suspension.**

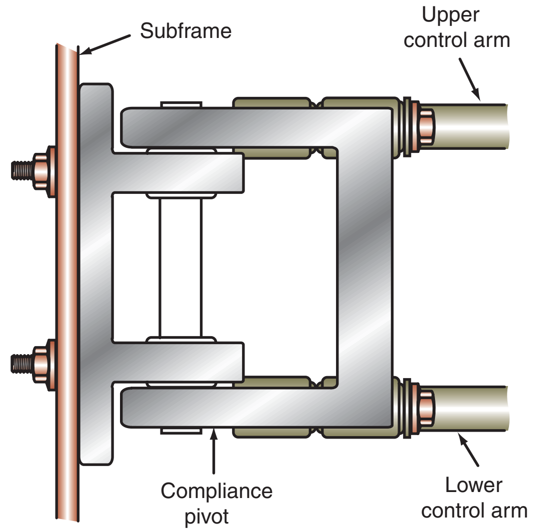

FIGURE 6-41 **Compliance pivot on double wishbone front suspension.**

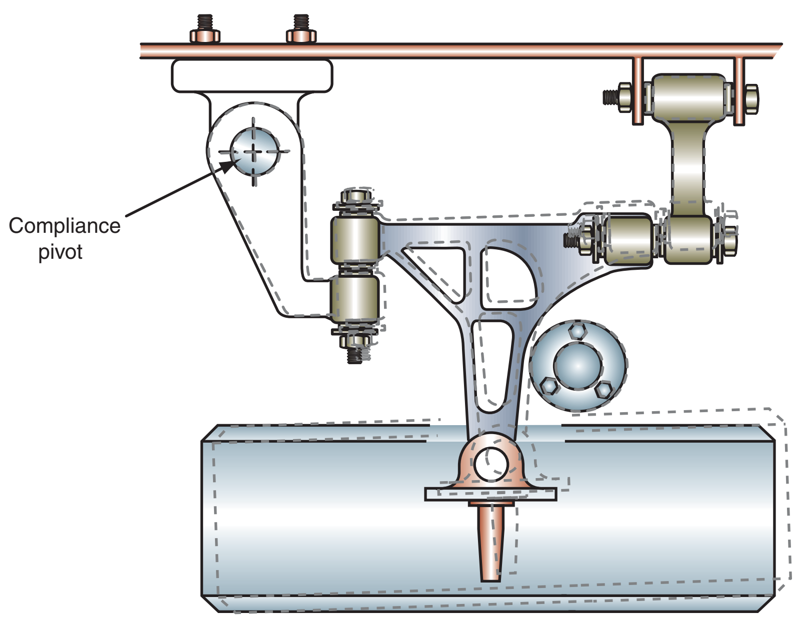

FIGURE 6-42 **Compliance pivot action.**

Multilink Front Suspension with Compression and Lateral Lower Arms

Some lateral multilink front suspensions have compression and lateral lower arms. The lateral arm prevents front wheel movement, and the compression arm prevents fore-and-aft front wheel movement. A rubber insulating bushing in the inner end of the lateral arm is bolted to the chassis. A second rubber insulating bushing near the outer end of the lateral arm is bolted to the damper fork. The upper end of the damper fork is bolted to the front strut (Figures 6-43

and 6-44). A ball joint in the outer end of the lateral arm is bolted into the steering knuckle. A rubber insulating bushing in the inner end of the compression arm is bolted to the chassis, and a ball joint in the outer end of this arm is bolted into the steering knuckle.

The upper control arm is mounted higher so it is above the front tire. The higher upper control arm and the lateral and compression lower arms provide excellent suspension stability and steering control, especially during high-speed cornering or when driving on irregular road surfaces. A ball joint in the outer end of the upper control arm is attached to the top of the knuckle, and two shafts in the inner end of this arm are bolted into the strut tower (Figure 6-45). There are no provisions for camber or caster adjustments on this multilink front suspension.

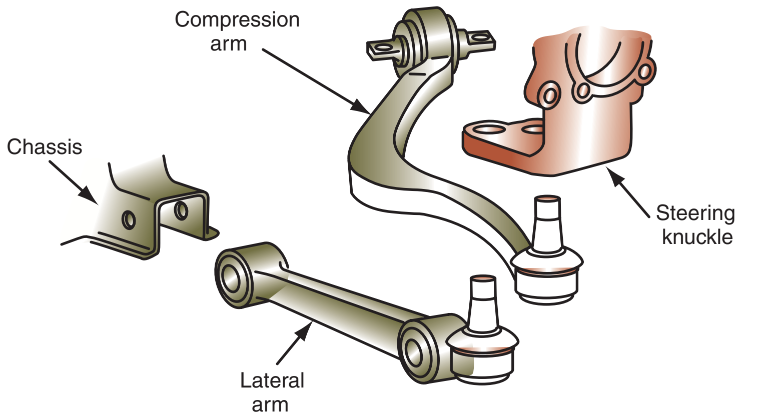

FIGURE 6-43 **Multilink front suspension with lateral and compression lower arms.**

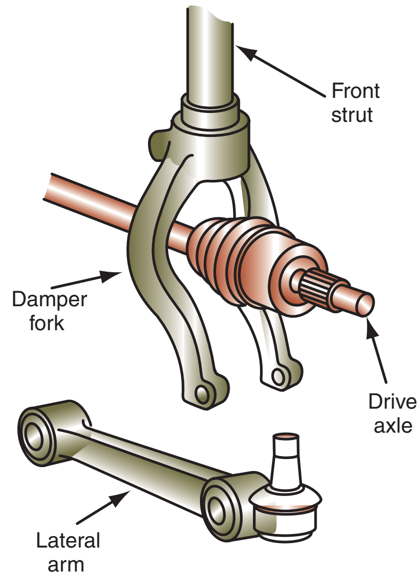

FIGURE 6-44 **Multilink front suspension damper fork.**

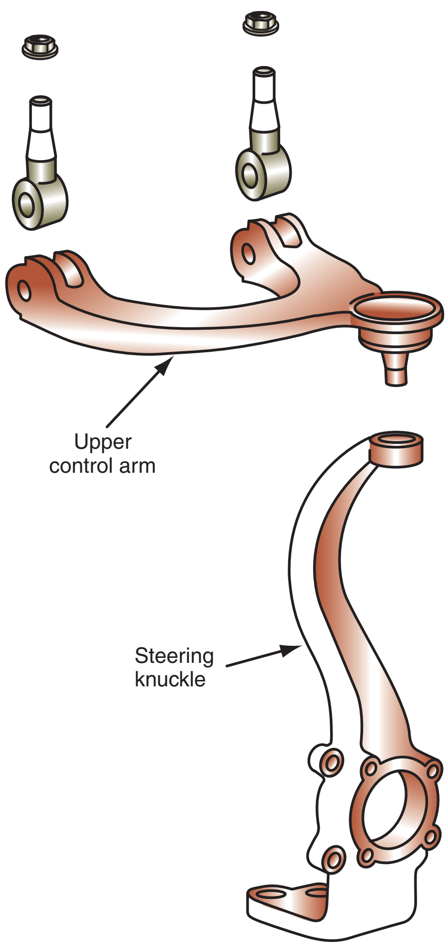

FIGURE 6-45 **Mutilink front suspension upper control arm.**

Torsion Bar Suspension

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Some light-duty trucks and sport utility vehicles (SUVs) have torsion bar front suspension systems. These suspension systems have longitudinally mounted torsion bars. The front and rear ends of the torsion bars have a hex shape. The front end of each torsion bar is anchored in the upper or lower control arm and the rear end of the torsion bars are anchored to a chassis crossmember (Figure 6-46). Since the twisting of the torsion bars supports the vehicle weight, the torsion bars replace the coil springs.

Torsion bar front suspension systems are often used on four-wheel-drive trucks, because the absence of coil springs allows more space for the front drive axles. On some torsion bar front suspension systems the torsion bars are anchored into the upper control arms rather than the lower control arms.

Vehicle ride height is controlled by the torsion bar anchor adjusting bolts in the crossmember. Front suspension heights must be within specifications for correct wheel alignment, tire wear, satisfactory ride, and accurate bumper heights. A conventional stabilizer bar is connected between the lower control arms and the crossmember. Ball joints are located in the upper and lower control arms, and both ball joints are bolted into the steering knuckle. The shock absorbers are connected between the lower control arms and the crossmember support, and the inner ends of the lower control arms are bolted to the crossmember through an insulating bushing (Figure 6-47).

Twin I-Beam Suspension Systems

Some Ford trucks are equipped with twin I-beam front suspension systems. In this type of suspension system, each front wheel is connected to a separate I-beam. The outer ends of the I-beam are connected to the spindles, and the inner ends of the beams are connected through a rubber pivot bushing to the chassis (Figure 6-48). Coil springs are positioned between the I-beams and the chassis to support the vehicle weight. Radius arms are connected rearward from each I-beam to the chassis to prevent longitudinal wheel movement. Since each front wheel can move independently in a twin I-beam suspension system, the problems associated with straight I-beam systems are greatly reduced.

In some I-beam front suspension systems, kingpins are used to attach the I-beams to the spindles. In other I-beam suspension systems, ball joints connect the I-beams to the spindles.

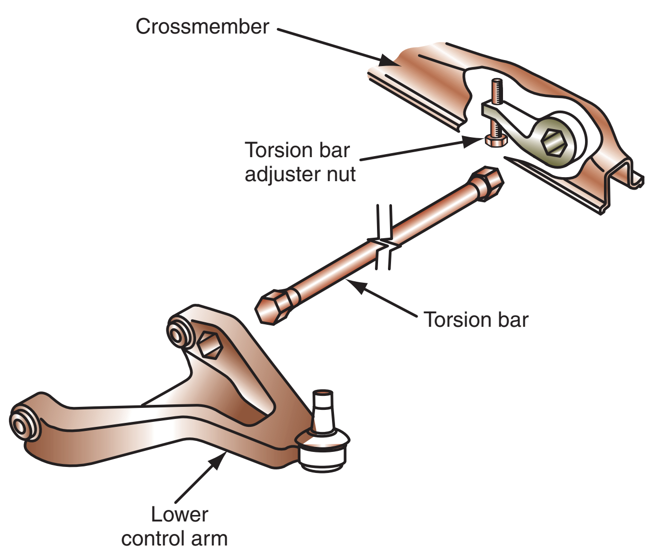

FIGURE 6-46 **Torsion bar mounting.**

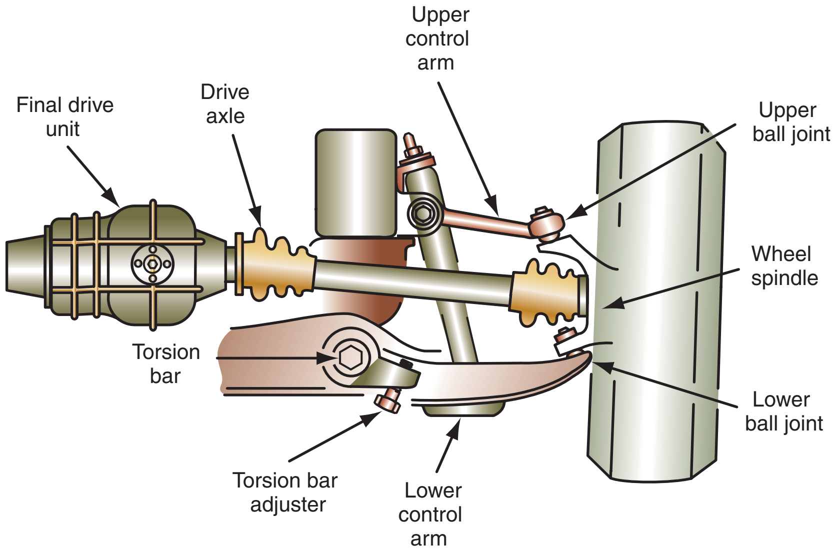

FIGURE 6-47 **Front suspension system with longitudinal torsion bars.**

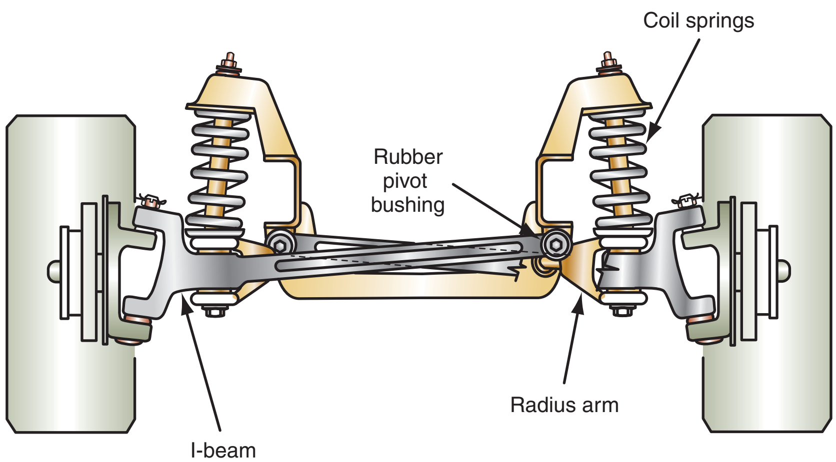

FIGURE 6-48 **Twin I-beam front suspension.**

Light-Duty Four-Wheel-Drive Truck Front Suspension Systems

Ford light-duty four-wheel-drive trucks have twin I-beam front suspension systems. F-150 four-wheel-drive models have a coil spring twin I-beam front suspension (Figure 6-49). The lower ends of the coil springs are seated on the twin I-beams, and the upper spring seat is positioned on the chassis. Heavy radius arms are bolted to the twin I-beams, and the other ends of the radius arms are mounted in a bushing and frame bracket (Figure 6-50). The radius arms prevent axle movement. The bushings in the inner ends of the twin I-beams are mounted on pivots attached to the front crossmember. Since each front wheel can move independently, twin I-beam suspensions are independent suspension systems. Upper and lower ball joints are pressed in the ends of the steering knuckle. The studs on these ball joints extend through openings in the outer ends of the twin I-beams. The ball joint studs are retained in the twin I-beams with nuts and cotter pins. Universal joints in the outer ends of the drive axles allow simultaneous wheel rotation and wheel turning to the right or left. The right-side drive axle also has an inner universal joint near the differential.

Ford F-250 and F-350 four-wheel-drive trucks have a leaf spring twin I-beam front suspension system (Figure 6-51). U-bolts retain the leaf springs to the twin I-beams. A bushing in the front of the leaf spring eye is bolted into a frame bracket. The bushing in the rear spring

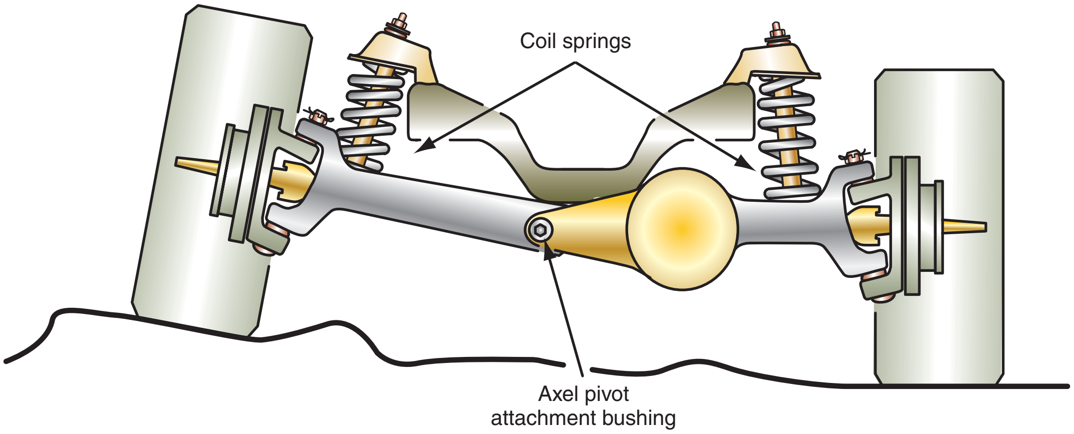

FIGURE 6-49 **Four-wheel-drive twin I-beam front suspension with coil springs.**

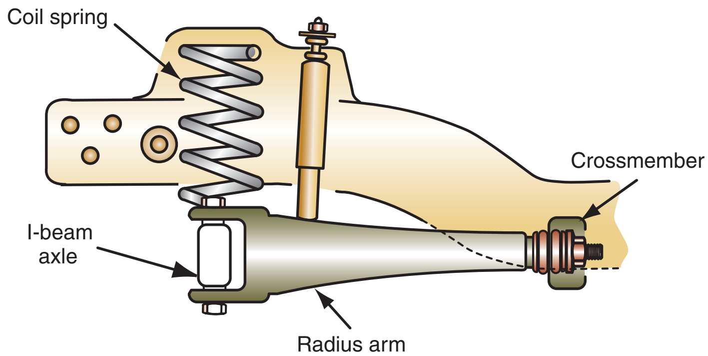

FIGURE 6-50 **Radius arms on a twin I-beam front suspension system with coil springs.**

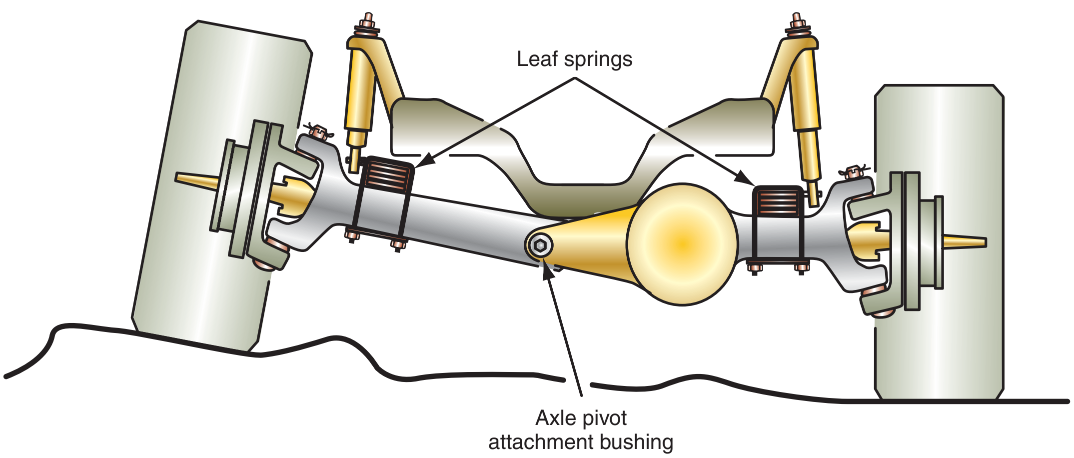

FIGURE 6-51 **Four-wheel-drive twin I-beam front suspension system with leaf springs.**

eye is connected to the frame through a conventional spring shackle (Figure 6-52). Since the leaf springs maintain the axle position, the radius arms are not required.

Some light-duty four-wheel-drive trucks have a straight front drive axle housing and a coil spring suspension system (Figure 6-53). Upper and lower radius rods control fore-and-aft drive axle movement, and a track bar controls lateral axle movement. Ball joints connect the steering knuckles to the outer ends of the drive axle housing.

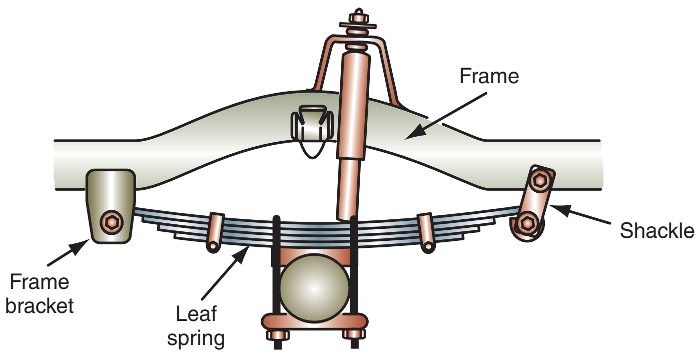

FIGURE 6-52 **Leaf spring mounting, four-wheel-drive twin I-beam front suspension.**

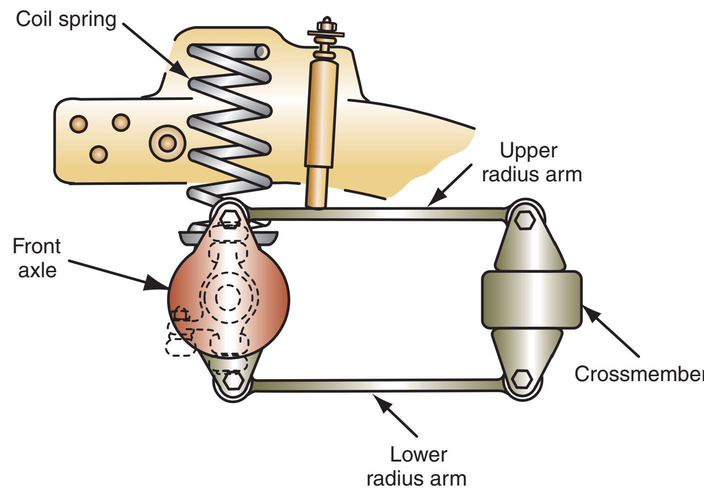

FIGURE 6-53 **Four-wheel-drive front suspension with straight drive axle and coil springs.**

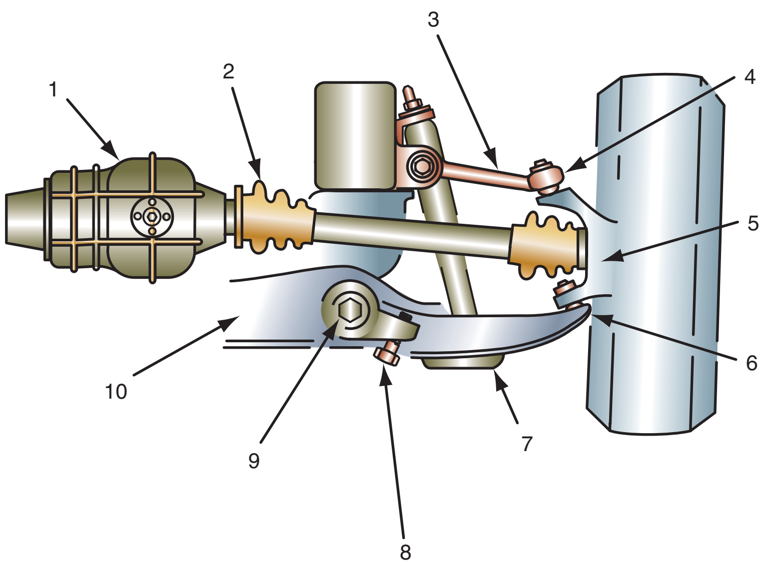

FIGURE 6-54 **Four-wheel-drive light-duty truck torsion bar front suspension.**

ITEM	DESCRIPTION
1	Final drive unit
2	Drive axle
3	Upper control arm
4	Upper ball joint
5	Steering knuckle
6	Lower ball joint
7	Lower control arm
8	Torsion bar adjuster
9	Torsion bar
10	Crossmember

FIGURE 6-55 **Component identification light-duty four-wheel-drive truck torsion bar front suspension.**

Other light-duty four-wheel-drive trucks have a torsion bar front suspension system with upper and lower control arms (Figures 6-54 and 6-55). The front of the torsion bars have hex-shaped ends that are mounted in a matching hex in the lower control arm. The hex-shaped rear ends of the torsion bars are mounted in adjusting arms that are retained in the torsion bar crossmember. An adjusting bolt in this crossmember contacts the outer end of each adjusting arm (Figure 6-56). Rotation of this adjusting bolt changes the tension on the torsion bar to adjust the curb riding height. On this type of torsion bar front suspension system, the front wheel bearing hubs are a prelubricated, sealed, non-serviceable assembly (Figure 6-57).

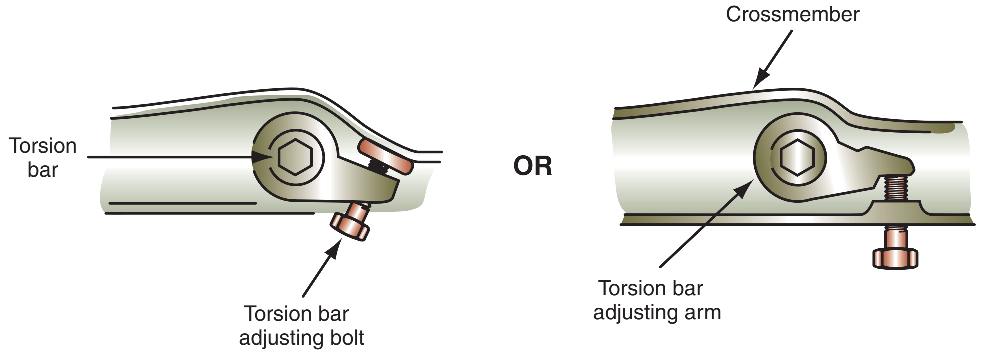

FIGURE 6-56 **Torsion bar adjusting arm and adjusting bolt.**

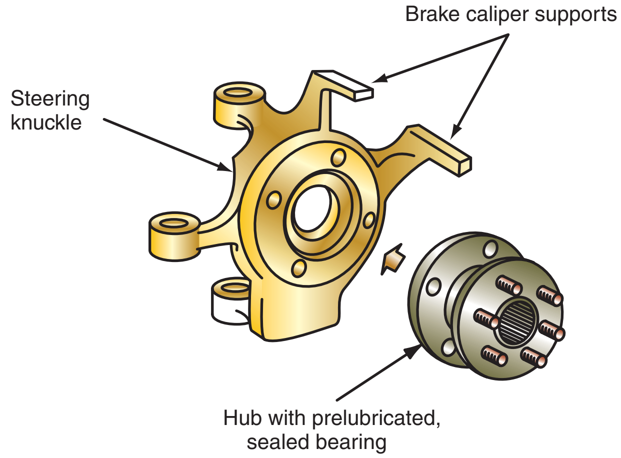

FIGURE 6-57 **Four-wheel-drive torsion bar front suspension with sealed non-serviceable front wheel bearing hubs.**

Twin I-beam front suspension systems have recently been replaced with short-and-long arm or torsion bar suspension systems, because these systems are lighter weight and provide improved ride quality.

Curb Riding Height

Regular inspection and proper maintenance of suspension systems are extremely important to maintain vehicle safety. The curb riding height is determined mainly by spring condition. Other suspension components such as control arm bushings will affect curb riding height if they are worn. Since incorrect curb riding height affects most of the other suspension angles, this measurement is critical. Sagged springs change the normal operating arc of the lower ball joint. This action causes excessive lateral movement of the tire during wheel jounce and rebound with resulting tire wear (Figure 6-58).

The curb riding height must be measured at the vehicle manufacturer's specified location, which varies depending on the type of suspension system. When the vehicle is on a level floor or an alignment rack, measure the curb riding height from the floor to the manufacturer's specified location on the chassis.

Caster angle is the tilt of an imaginary line through the center of the upper strut mount and ball joint in relation to the true vertical line through the center of the wheel and spindle as viewed from the side.

Front Spring Sag, Curb Riding Height, and Caster Angle

Sagged springs cause insufficient curb riding height. Therefore, the distance is reduced between the rebound bumper and its stop. This distance reduction causes the bumper to hit

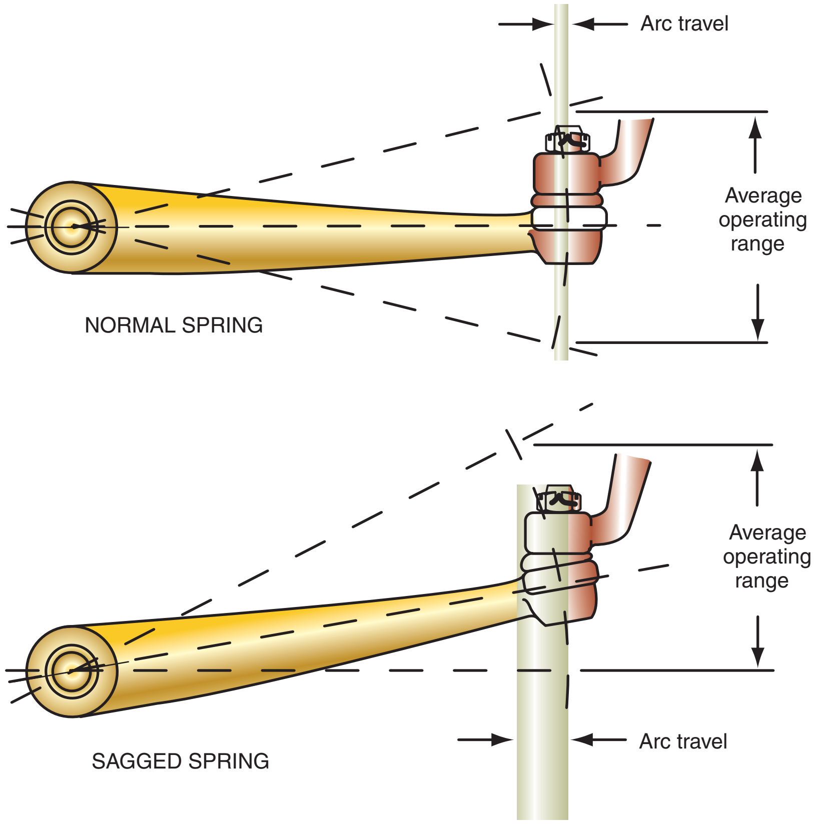

FIGURE 6-58 **Sagged springs change the normal operating arc of the lower ball joint and cause excessive lateral tire movement during wheel jounce and rebound with resulting tire wear.**

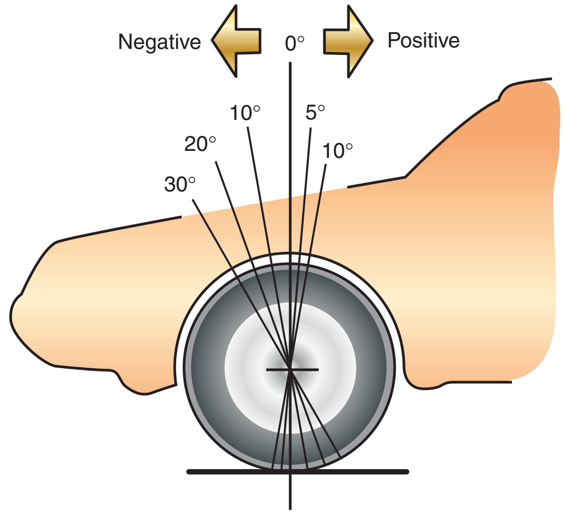

FIGURE 6-59 **Positive and negative caster.**

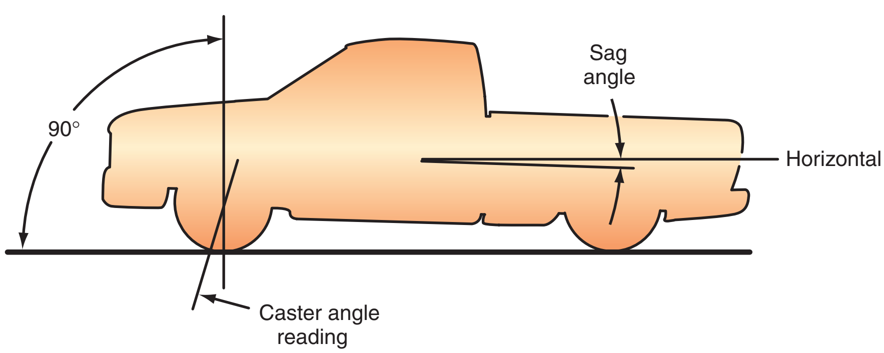

FIGURE 6-60 **Effects of rear spring sag and incorrect curb riding height on caster angle.**

the stop frequently with resulting harsh ride quality. The caster angle is the number of degrees between the true vertical centerline of the tire and wheel, and an imaginary line through the center of the upper strut mount and lower ball joint. Positive caster angle occurs when the caster line is tilted toward the rear of the vehicle. Negative caster angle is present when the caster line is tilted toward the front of the vehicle (Figure 6-59).

When both rear springs are sagged, the caster angle tilts excessively toward the rear of the vehicle (Figure 6-60). This caster angle results in increased steering effort and rapid steering wheel return after a turn.

If both front springs are sagged, the caster angle tilts excessively toward the front of the vehicle (Figure 6-61). When the front springs are sagged and caster is negative, directional stability is decreased, and the front wheels tend to wander.

Directional stability refers to the tendency of the steering to remain in the straight-ahead position with very little correction by the driver when the vehicle is driven on a smooth, level road surface. Certain suspension defects reduce directional stability and cause the steering to pull to one side.

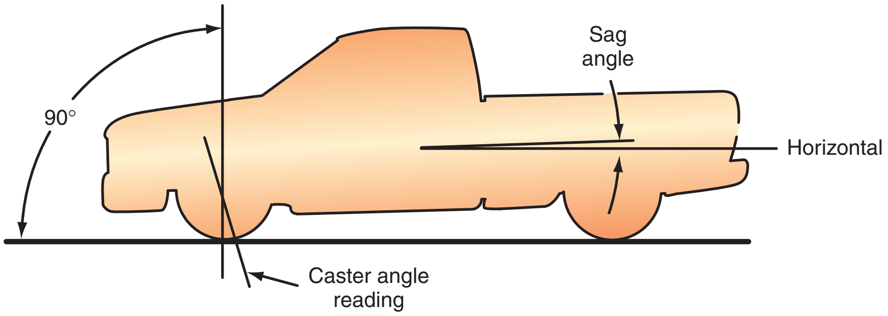

FIGURE 6-61 **Effects of front spring sag on caster angle.**

Camber angle is the tilt of a line through the center of the wheel in relation to the vertical centerline viewed from the front of the wheel.

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Spring Sag, Curb Riding Height, and Camber Angle

Positive camber occurs when the camber line is tilted outward from the vertical centerline of the wheel. If the camber line is tilted inward from the vertical centerline of the wheel, the camber is said to be negative (Figure 6-62).

If a spring is sagged on one side of the front suspension, the camber angle is negative on that side. Excessive negative camber results in rapid wear on the inside edge of the tire tread and a decrease in directional stability. *Therefore, curb riding height is extremely important to maintaining correct wheel alignment angles, normal tire wear, and satisfactory directional stability.* When the curb riding height does not meet the vehicle manufacturer's specifications, check for bent control arms and worn control arm bushings or mounting bolts. If these components are satisfactory, spring replacement is required to correct the curb riding height.

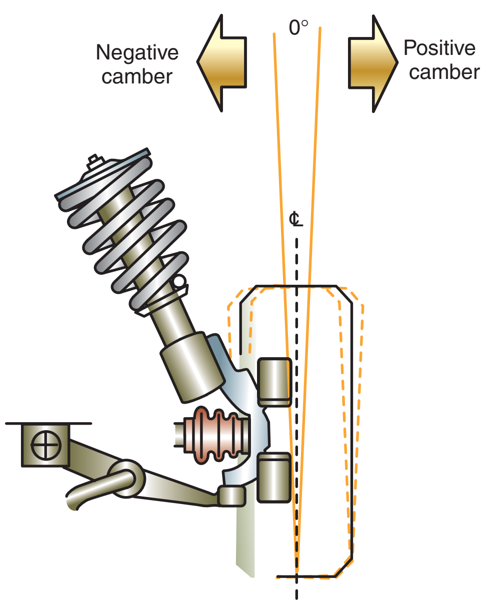


FIGURE 6-62 **Positive and negative camber.**

Summary

- Coil springs may be classified as linear rate or variable rate.
- A linear-rate coil spring has a constant spring rate regardless of spring load.
- Variable-rate coil springs have unequally spaced coils. The coils in these springs may be referred to as inactive, transitional, or active.
- Heavy-duty coil springs have larger-diameter wire than regular-duty coil springs.
- Most vehicle manufacturers recommend that springs be replaced in pairs.
- In a torsion bar suspension system, the torsion bars replace the coil springs.
- Torsion bars are directional, and they are marked right or left.
- In a leaf spring, zinc and plastic spacers between the leaves reduce noise and friction problems.
- Leaf springs may be mono-leaf or multiple-leaf design.
- Spring leaves may be manufactured from steel or fiberglass.
- Although many leaf springs are mounted longitudinally, some of these springs are mounted transversely.
- Ball joints may be classified as load-carrying or non-load-carrying.
- A load-carrying ball joint may be compression loaded or tension loaded.
- The load-carrying ball joint wears faster than the non-load-carrying ball joint.
- Many ball joints have wear indicators that provide visual ball joint wear inspection.
- A stabilizer bar reduces body roll or sway when one front wheel strikes a road irregularity.
- A strut rod prevents fore-and-aft lower control arm movement.
- In many MacPherson strut front suspension systems, the lower end of the strut is bolted to the steering knuckle, and the upper end of the strut is connected through an upper mount to the fender reinforcement.
- Torsion bars may be transversely or longitudinally mounted in a front suspension system.
- In a short-and-long arm suspension system, the coil springs may be mounted between the lower control arm and the frame or between the upper control arm and the chassis.
- In a twin I-beam suspension system, the spindles may be connected to the I-beams with kingpins or ball joints.
- Curb riding height is extremely important for maintaining normal tire wear and proper suspension alignment angles.

Terms to Know

Active coils
Compression loaded
Full-wire open-end springs
Gussets
Heavy-duty coil springs
Inactive coils
Linear-rate coil springs
Load-carrying ball joint
MacPherson strut front suspension systems
Mono-leaf springs
Multilink front suspension
Multiple-leaf springs
Non-load-carrying ball joint
Pigtail spring ends
Regular-duty coil springs
Short-and-long arm front suspension systems
Sprung weight
Taper-wire closed-end springs
Tension loaded
Transitional coils
Unsprung weight
Variable-rate coil springs
Wear indicators

Review Questions

Short Answer Essays

1. Explain the meaning of constant spring rate.
2. Describe the main difference in the design of heavy-duty coil springs compared with regular-duty coil springs, and compare the free diameter of each type of spring.
3. Explain the type of load condition that requires variable-rate coil springs, and describe the load-carrying advantage of these springs.
4. Describe the design of taper-wire closed-end springs.
5. Explain torsion bar action during wheel jounce and rebound.
6. Describe the action of a leaf spring as it compresses.
7. Explain the position of the lower control arm when the lower ball joint is compression loaded.
8. Describe the position of the wear indicator when a ball joint is worn.

9. Explain the basic purpose of the lower control arms.
10. Describe the effect of sagged front springs on caster angle and directional stability.

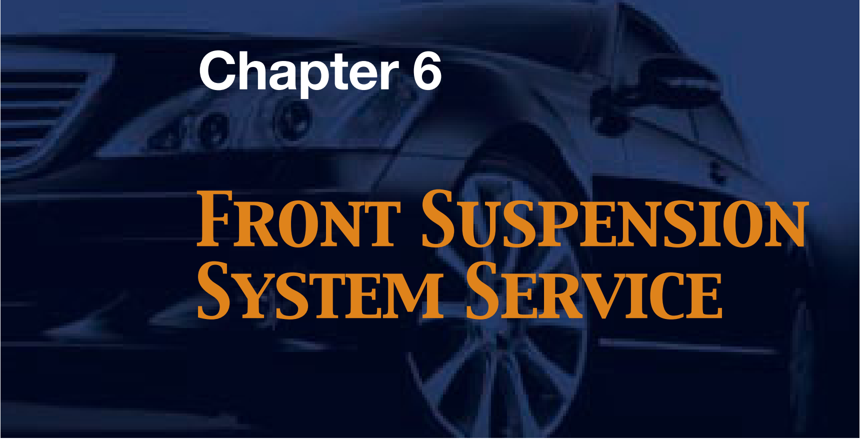
Fill-in-the-Blanks

1. Heavy-duty coil springs are designed to carry _______________ to _______________ percent greater loads than regular-duty coil springs.
2. A variable-rate coil spring provides automatic _______________ adjustment.
3. In a variable-rate spring, the _______________ coils operate during the complete range of spring loading.
4. The load-carrying ball joint is attached to the control arm on which the _______________ _______________ is seated.
5. If the lower control arm is mounted above the steering knuckle and rests on the knuckle, the lower ball joint is _______________ _______________.
6. When the grease nipple shoulder is extended from the ball joint housing, the ball joint is _______________.
7. When one front wheel strikes a road irregularity, the stabilizer bar reduces _______________ _______________.
8. The strut rod prevents _______________ and _______________ lower control arm movement.
9. When the front springs are sagged, the positive caster is _______________.
10. If a front spring is sagged, the camber angle moves toward a _______________ position.

Multiple Choice

1. A 400-pound load deflects a linear-rate coil spring 1 inch. An 800-pound load will deflect this coil spring:
   A. 1.5 inches.
   B. 2 inches.
   C. 3 inches.
   D. 4 inches.
2. Heavy-duty coil springs have:
   A. The same wire diameter as a regular-duty coil spring.
   B. A shorter free height compared to a regular-duty coil spring.
   C. A 10 percent increase in load carrying capacity.
   D. A high aluminum content in the spring material.
3. A car's rear coil springs keep breaking. This problem is likely due to:
   A. Continual driving on rough road surfaces.
   B. Continual driving on curved roads.
   C. Excessive air pressure in the rear tires.
   D. Constant overloading of the rear suspension.
4. Aluminum control arms have all of these advantages EXCEPT:
   A. Reduce unsprung weight.
   B. Provide improved road feel.
   C. Provide improved ride quality.
   D. Contribute to improved fuel economy.
5. While discussing a torsion bar front suspension system:
   A. One end of the torsion bar is attached to the upper control arm.
   B. A suspension height adjustment is positioned on the end of the torsion bar connected to the control arm.
   C. Torsion bars may be mounted longitudinally or transversely in a front suspension system.
   D. Torsion bars eliminate the need for shock absorbers in the front suspension system.
6. While discussing leaf springs:
   A. A fiberglass mono-leaf spring is heavier than a steel mono-leaf spring.
   B. Some mono-leaf springs are mounted transversely.
   C. In a multiple-leaf spring, the lower leaf is called the main leaf.
   D. A multiple-leaf spring has the same stiffness regardless of how much it is compressed.
7. All these statements about ball joints are true EXCEPT:
   A. A load-carrying ball joint wears faster than a non-load-carrying ball joint.
   B. A non-load-carrying ball joint is designed with a preload.
   C. Wear indicators may be positioned in the side of the ball-joint housing.
   D. Low-friction ball joints have a highly polished ball socket surrounded by a high-strength polymer bearing.

8. While discussing MacPherson strut suspension systems:
   A. During a turn, the strut, spring, and knuckle rotate on the upper strut mount.
   B. The lower end of the coil spring is seated on the lower control arm.
   C. The strut is welded into the knuckle and these components are replaced as an assembly.
   D. The inner ends of the lower control arms are bolted to the strut.
9. While discussing short-and-long arm front suspension systems:
   A. The coil springs are positioned between the upper and lower control arms.
   B. Compared with a suspension system with equal length control arms, the short-and-long design reduces track width change and tire wear.
   C. The outer ends of the stabilizer bar may be attached to the steering knuckles.
   D. The coil spring is retained in the lower control arm with a clamp and bolt.
10. While discussing sagged springs:
    A. Sagged front springs cause harsh riding.
    B. Sagged front springs cause excessive positive caster on the front wheels and increased directional stability.
    C. Sagged rear springs cause excessive negative caster on the front wheels.
    D. Sagged rear springs cause excessive positive camber on the front wheels.



Chapter 6

Front Suspension System Service

Upon completion and review of this chapter, you should be able to:

- Measure curb riding height.
- Diagnose and correct curb riding height problems.
- Adjust torsion bars.
- Diagnose front suspension noise and body sway.
- Remove and replace ball joints, and check ball joint condition.
- Remove and replace steering knuckles, and check knuckle condition.
- Remove and replace lower control arms, and check control arm and bushing condition.
- Remove and replace coil springs, and check spring and insulator condition.
- Remove and replace upper control arms, and check control arm and bushing condition.
- Remove and replace control arm bushings.
- Inspect and replace rebound bumpers.
- Diagnose, remove, and replace stabilizer bars.
- Diagnose, remove, and replace strut rods.
- Diagnose, remove, and replace leaf springs.
- Replace torsion bars, and check torsion bar condition.

Proper front suspension system service is extremely important to provide adequate vehicle safety and to maintain ride comfort and normal tire life. If worn or loose front suspension system components are ignored, steering control may be adversely affected, which may result in loss of steering control and an expensive collision. Defective front suspension components, such as worn out shock absorbers or broken springs, may cause rough riding that results in driver and passenger discomfort. Other worn front suspension components, such as worn ball joints and control arm bushings, cause improper alignment angles that causes excessive front tire wear. Therefore, technicians must be familiar with front suspension service.

BASIC TOOLS

Basic technician's tool set

Service manual

Floor jack

Safety stands

Pry bar

3/8" electric drill and drill bits

Curb Riding Height Measurement

Regular inspection and proper maintenance of suspension systems is extremely important for maintaining vehicle safety. The **curb riding height** is determined mainly by spring condition. Other suspension components, such as control arm bushings, affect curb riding height if they are worn. Since incorrect curb riding height affects most of the other suspension angles, this measurement is critical.

Curb riding height is the distance from specific chassis locations to the road surface.

Reduced curb riding height on the front suspension may cause decreased **directional stability**. If the curb riding height is reduced on one side of the front suspension, the steering may pull to one side. Reduced rear suspension height increases **steering effort** and causes rapid steering wheel return after turning a corner. Harsh riding occurs when the curb riding

Directional stability refers to the tendency of the vehicle steering to remain in the straight-ahead position when driven straight ahead on a reasonably smooth, level road surface.

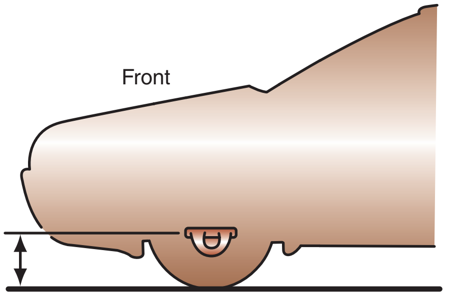


FIGURE 6-1 **Curb riding height measurement, front suspension.**

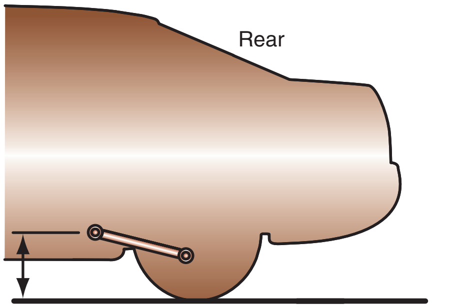


FIGURE 6-2 **Curb riding height measurement, rear suspension.**

Steering effort is the amount of effort required to turn the steering wheel.

height is less than specified. The curb riding height must be measured at the vehicle manufacturer's specified location, which varies depending on the type of suspension system.

When the vehicle is on a level floor or on an alignment rack, measure the curb riding height from the floor to the center of the lower control arm mounting bolt on both sides of the front suspension (Figure 6-1). On the rear suspension system, measure the curb riding height from the floor to the center of the strut rod mounting bolt (Figure 6-2).

If the curb riding height is less than specified, the control arms and bushings should be inspected and replaced as necessary. When the control arms and bushings are in normal condition, the reduced curb riding height may be caused by sagged springs that require replacement.

Front Suspension Diagnosis and Service

Torsion Bar Adjustment

Customer Care: Each time under-car service is performed, make a quick inspection of suspension and steering components. Advise the customer regarding any necessary repairs. This procedure often obtains additional work for the shop, and the customer will be impressed that you are interested in his or her car and personal safety.

SPECIAL TOOLS

Machinist's rule

On torsion bar front suspension systems, the torsion bars may be adjusted to correct the curb riding height. The curb riding height must be measured at the location specified by the vehicle manufacturer. On some torsion bar front suspension systems, the curb riding height is measured with the vehicle on a lift and the tires supported on the lift. Measure the distance from the center of the front lower control arm bushing to the lift. Then measure the distance from the lower end of the front spindle to the lift (Figure 6-3). The difference between these two readings is the curb riding height.

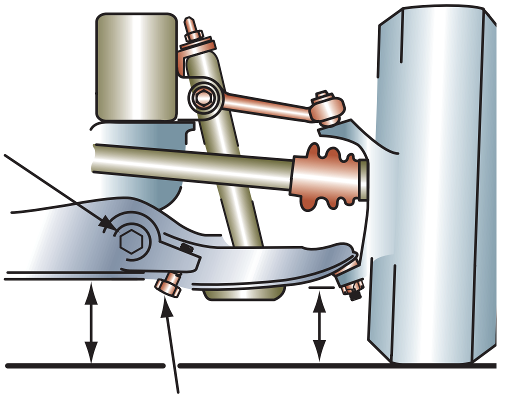


FIGURE 6-3 **Curb riding height measurement, torsion bar front suspension.**

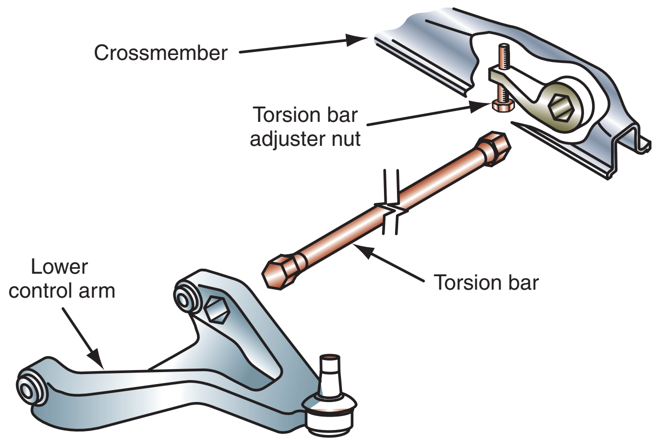


FIGURE 6-4 **Curb riding height adjustment, torsion bar front suspension.**

If the curb riding height is not correct on a torsion bar front suspension, the torsion bar anchor adjusting bolts must be rotated until the curb riding height equals the vehicle manufacturer's specifications (Figure 6-4).

Inspecting Ball Joints

CUSTOMER CARE: Regular chassis lubrication at the vehicle manufacturer's recommended service interval is one of the keys to long ball joint life. Always advise the customer of this fact.

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Wear Indicators. Some ball joints have a grease fitting installed in a floating retainer. The grease fitting and retainer may be used as a **ball joint wear indicator**. With the vehicle weight resting on the wheels, grasp the grease fitting and check for movement (Figure 6-5).

Some car manufacturers recommend ball joint replacement if any grease fitting movement is present. In some other ball joints, the grease fitting retainer extends a short distance through the ball joint surface (Figure 6-6). On this type of joint, replacement is necessary if the grease fitting shoulder is flush with or inside the ball joint cover.

A **ball joint wear indicator** allows the technician to check ball joint wear by visibly inspecting the ball joint.

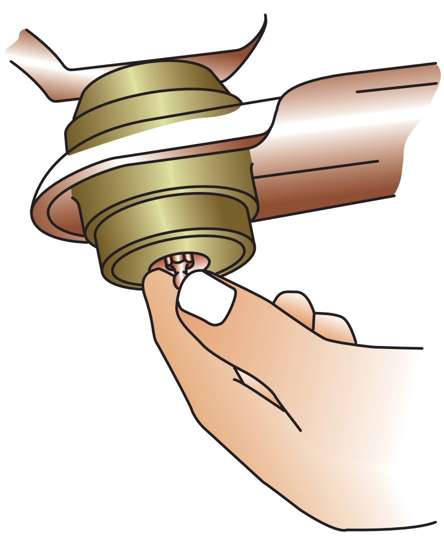


FIGURE 6-5 **Ball joint grease fitting wear indicator.**

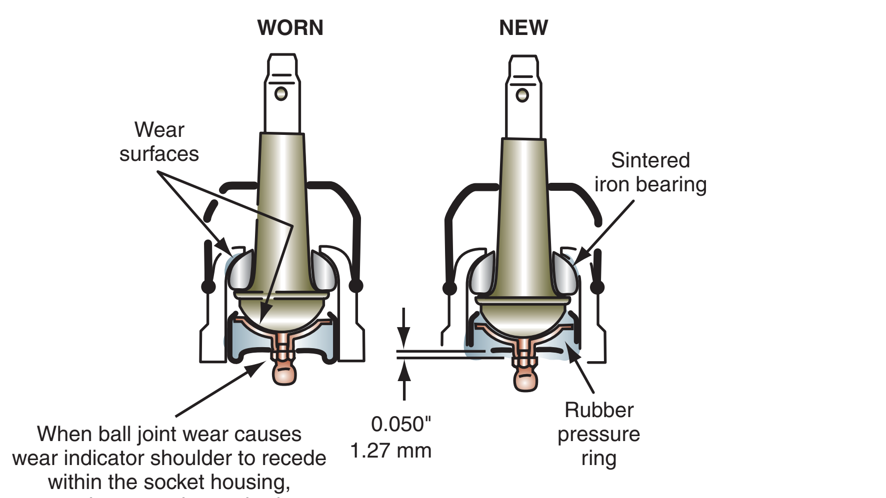


FIGURE 6-6 **Ball joint wear indicator with grease fitting extending from ball joint surface.**

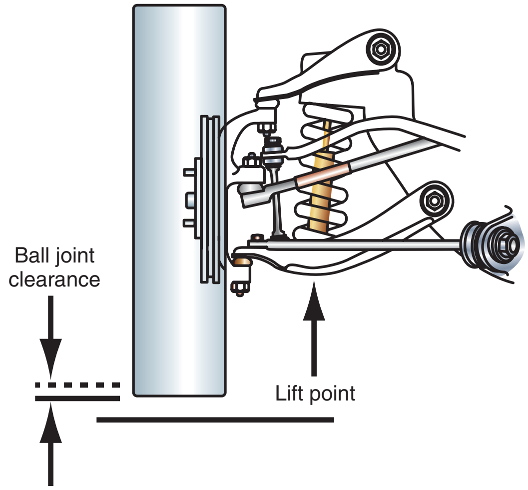


FIGURE 6-7 **Floor jack position to check ball joint wear with spring between the lower control arm and the chassis.**

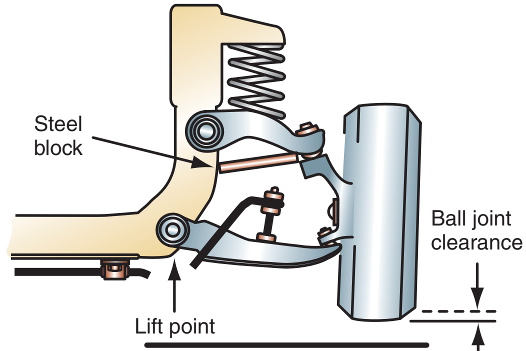


FIGURE 6-8 **Floor jack position to check ball joint wear with spring between the upper control arm and the chassis.**

Ball Joint Unloading

On many suspension systems, ball joint looseness is not apparent until the weight has been removed from the joint. When the coil spring is positioned between the lower control arm and the chassis, place a floor jack near the outer end of the lower control arm and raise the tire off the floor (Figure 6-7). Be sure the rebound bumper is not in contact with the control arm or frame.

When the coil springs are positioned between the upper control arm and the chassis, place a steel block between the upper control arm and the frame. With this block in place, raise the tire off the floor with a floor jack under the front crossmember (Figure 6-8).

SPECIAL TOOLS

Dial indicator for ball joint measurement

Ball joint vertical movement refers to up and down movement in a ball joint.

Ball Joint Vertical Measurement

The vehicle manufacturer may provide ball joint vertical and horizontal tolerances. A dial indicator is one of the most accurate ball joint measuring devices (Figure 6-9). Always install the dial indicator at the vehicle manufacturer's recommended location for ball joint measurement. When measuring the **ball joint vertical movement** in a compression-loaded ball joint, attach the dial indicator to the lower control arm and position the dial indicator stem on the lower side of the steering knuckle beside the ball joint stud (Figure 6-10). Depress the dial

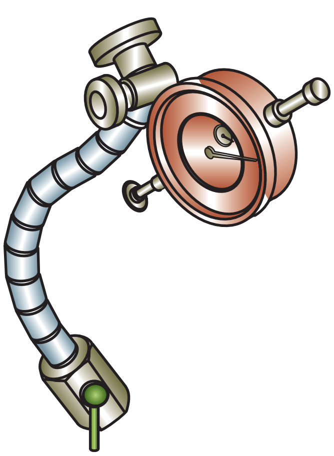


FIGURE 6-9 **Dial indicator designed for ball joint measurement.**

FIGURE 6-10 **Dial indicator installed to measure vertical ball joint movement on a compression-loaded ball joint.**

indicator stem approximately 0.250 in. (6.35 mm) and zero the dial indicator. Place a pry bar under the tire and pry straight upward while observing the vertical ball joint movement on the dial indicator. If this movement is more than specified, ball joint replacement is necessary. Photo Sequence 9 illustrates the vertical ball joint measurement procedure.

On a tension-loaded ball joint, clean the top end of the lower ball joint stud, and position the dial indicator stem against the top end of this stud. Depress the dial indicator plunger approximately 0.250 in (6.35 mm) and zero the dial indicator. Lift upward with a pry bar under the tire and observe the dial indicator reading. If the vertical ball joint movement exceeds the manufacturer's specifications, ball joint replacement is required.

Camber angles are an imaginary line through the centerline of the tire and wheel in relation to the true vertical centerline of the tire.

Ball Joint Horizontal Measurement

Worn ball joints cause improper **camber angles** and **caster angles**, which result in reduced directional stability and tire tread wear. Connect the dial indicator to the lower control arm of the ball joint being checked and position the dial indicator stem against the edge of the wheel rim (Figure 6-11).

Caster angles are an imaginary line through the upper and lower ball joint centers in relation to the true vertical tire centerline viewed from the side.

Be sure the front wheel bearings are adjusted properly prior to the ball joint horizontal measurement. While an assistant grasps the top and bottom of the raised tire and attempts to move the tire and wheel horizontally in and out, observe the reading on the dial indicator (Figure 6-12).

Diagnosis of Ride Harshness

When diagnosing a ride harshness condition, check these measurements and components:

1. Curb riding height—insufficient curb riding height causes ride harshness
2. Excessive vehicle load
3. Worn shock absorbers or struts
4. Broken or weak springs
5. Worn suspension bushings, such as strut mounts, control arm bushings, and shock absorber mounting bushings
6. Wheel alignment—excessive positive caster on front wheels causes ride harshness

Noise Diagnosis

A squeaking noise in the rear suspension may be caused by a suspension bushing or a defective strut or shock absorber.

FIGURE 6-11 **Dial indicator installed to measure radial ball joint movement.**

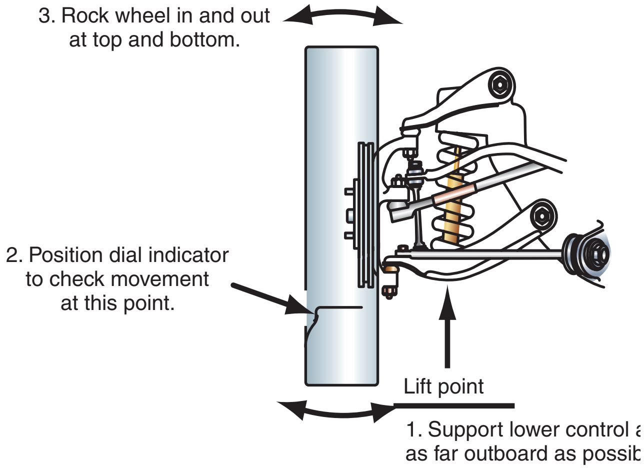


FIGURE 6-12 **Measuring radial ball joint movement.**

PHOTO SEQUENCE 9

Vertical Ball Joint Measurement

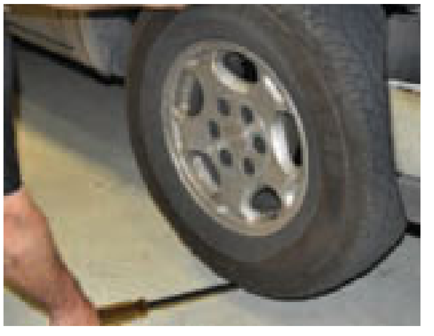
P9-1 **Place a floor jack under a front, lower control arm, and raise the lower control arm until the front tire is approximately 4 in. (10 cm) off the floor.**

P9-2 **Lower the lower control arm until it is securely supported on a safety stand, and remove the floor jack.**

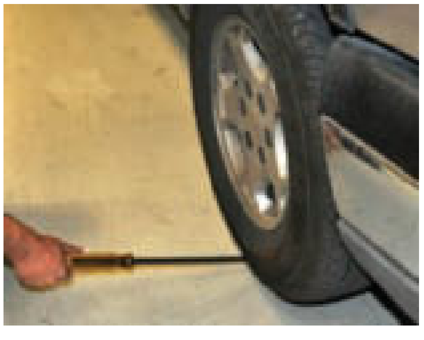
P9-3 **Attach the magnetic base of a dial indicator for measuring ball joints to the safety stand.**

P9-4 **Position the dial indicator stem against the steering knuckle beside the ball joint stud.**

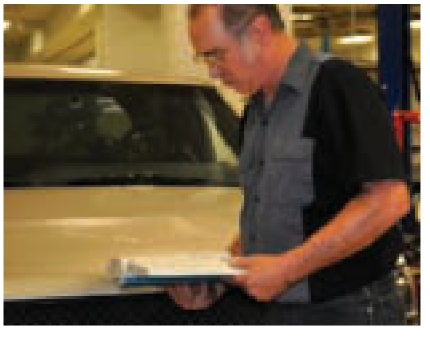
P9-5 **Preload the dial indicator stem approximately 0.250 in. (6.35 mm), and zero the dial indicator scale.**



P9-6 **Position a pry bar under the tire and lift on the tire-and-wheel assembly while a coworker observes the dial indicator. Record the ball joint vertical movement indicated on the dial indicator.**



P9-7 **Repeat step 6 several times to confirm an accurate dial indicator reading.**



P9-8 **Compare the ball joint vertical movement indicated on the dial indicator to the vehicle manufacturer's specifications for ball joint wear. If the ball joint vertical movement exceeds specifications, ball joint replacement is necessary.**

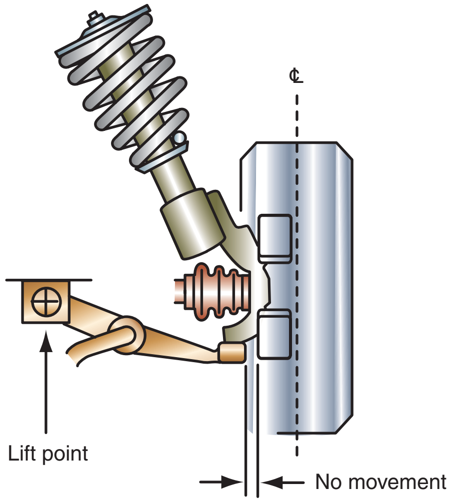


FIGURE 6-13 **Ball joint wear measurement on MacPherson strut front suspension.**

The lower ball joint on a MacPherson strut front suspension should be checked for radial movement with a dial indicator when the tire is lifted off the floor (Figure 6-13). Since the spring load is carried by the upper and lower spring seats when the tire is lifted off the floor, it is not necessary to unload this type of ball joint. Photo Sequence 10 shows a typical procedure for measuring the lower ball joint radial movement on a MacPherson strut front suspension.

Checking Ball Joints, Twin I-Beam Axles

Follow these steps to check the ball joints on a twin I-beam axle:

1. Lift the front end of the vehicle with a floor jack and place safety stands near the outer end of the I-beams.
2. Lower the vehicle onto the safety stands.
3. While an assistant grasps the wheel at the bottom and moves the wheel in and out, watch for movement between the lower part of the axle jaw and the spindle lower arm. If this movement exceeds 1/32 in., replace the lower ball joint.
4. As an assistant grasps the top of the wheel and moves the wheel in and out, watch for movement between the upper axle jaw and the spindle upper arm. If this movement exceeds 1/32 in., replace the upper ball joint.

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Front Steering Knuckle Diagnosis and Service, Front-Wheel-Drive Vehicle

Front Steering Knuckle Diagnosis. Steering looseness may be caused by a worn tie-rod end opening or ball joint opening in the steering knuckle. If these knuckle openings are worn, reduced directional stability may be experienced. Since a bent steering knuckle affects front suspension alignment angles, this problem may cause reduced directional stability and tire tread wear. Many steering arm and knuckle assemblies must be replaced as a unit. If the steering arms are bent, knuckle replacement is required.

Steering Knuckle Removal and Replacement. The steering knuckle replacement procedure varies depending on the type of front suspension. Always follow the vehicle manufacturer's steering knuckle replacement procedure in the service manual.

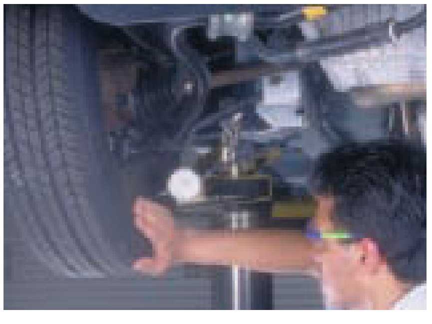
PHOTO SEQUENCE 10

Typical Procedure for Measuring the Lower Ball Joint Horizontal Movement on a MacPherson Strut Front Suspension

P10-1 **Raise the front suspension with a floor jack and place safety stands under the chassis at the vehicle manufacturer's recommended lifting points.**

P10-2 **Grasp the front tire at the top and bottom and rock the tire inward and outward while a coworker visually checks for movement in the front wheel bearing. If there is movement in the front wheel bearing, adjust or replace the bearing.**

P10-3 **Position a dial indicator against the inner edge of the rim at the bottom. Preload and zero the dial indicator.**

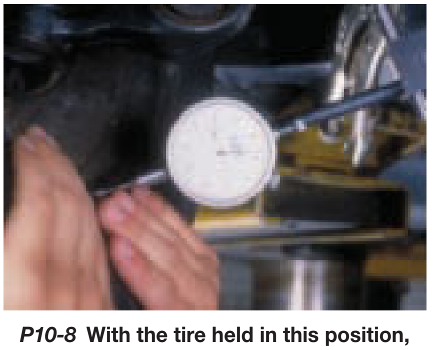


P10-4 **Grasp the bottom of the tire and pull outward.**

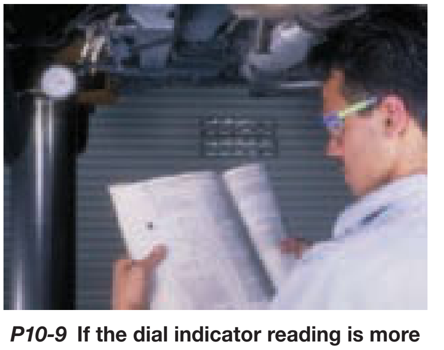
P10-5 **With the tire held outward, read the dial indicator.**

P10-6 **Push the bottom of the tire inward and be sure the dial indicator reading is zero. Adjust the dial indicator as required.**

P10-7 **Grasp the bottom of the tire and pull outward.**



P10-8 **With the tire held in this position, read the dial indicator.**



P10-9 **If the dial indicator reading is more than specified, replace the lower ball joint.**

Follow these steps to replace the steering knuckle on a front-wheel-drive vehicle with a MacPherson strut front suspension system:

1. Remove the wheel cover and loosen the front wheel nuts and the drive axle nut.
2. Lift the vehicle chassis on a hoist and allow the front suspension to drop downward. Remove the front wheel, brake caliper, brake rotor, and drive axle nut. Tie the brake caliper to a suspension component. Do not allow the caliper to hang on the end of the brake hose.
3. Remove the inner end of the drive axle from the transaxle with a pulling or prying action. On some Chrysler products, the differential cover must be removed and axle circlips compressed before the drive axle is removed from the transaxle.
4. Remove the outer end of the drive axle from the steering knuckle. On some early model Ford Escorts and Lynx, a puller is required for this operation.
5. Be sure the vehicle weight is supported on the hoist with the front suspension dropped downward. Disconnect the lower ball joint nuts from the mounting bolts in the lower control arm (Figure 6-14).
6. Remove the cotter pin from the outer tie-rod nut (Figure 6-15). Remove the outer tie-rod nut, and then use a puller to disconnect the tie-rod end from the steering knuckle (Figure 6-16).
7. If an eccentric cam is used on one of the strut-to-knuckle bolts, mark the cam and bolt position in relation to the strut, and remove the strut-to-knuckle bolts.
8. Remove the knuckle from the strut, and lift the knuckle out of the chassis (Figure 6-17).

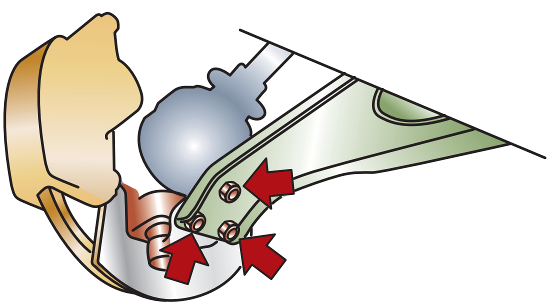


FIGURE 6-14 **Removing nuts from lower ball joint mounting bolts under the lower control arm.**

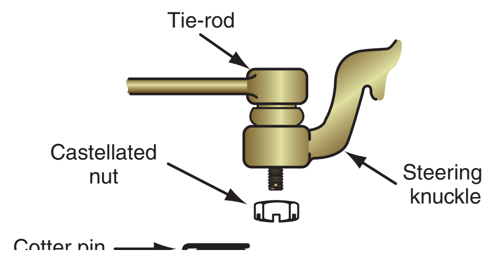


FIGURE 6-15 **Removing the cotter pin and nut from the outer tie-rod end.**

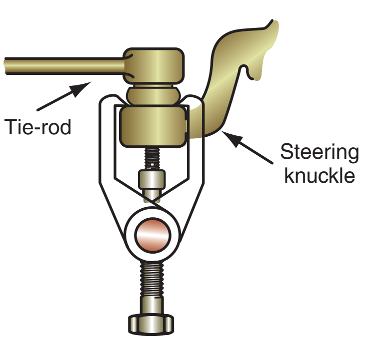


FIGURE 6-16 **Removing the outer tie-rod end from the steering knuckle.**

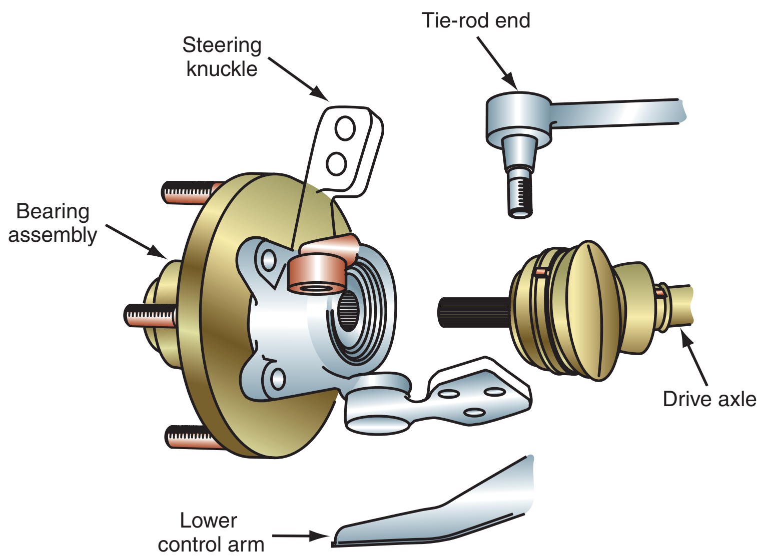


FIGURE 6-17 **Removing the steering knuckle from the lower control arm.**

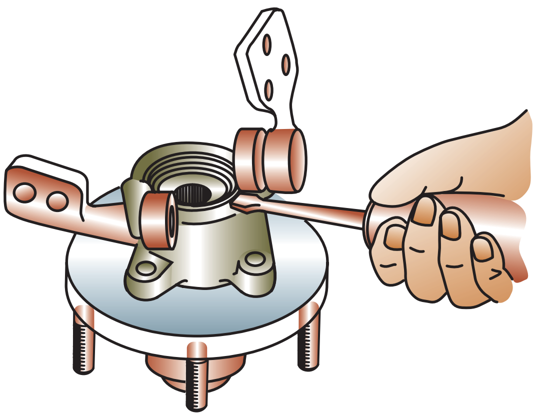


FIGURE 6-18 **Removing dust deflector from the steering knuckle.**

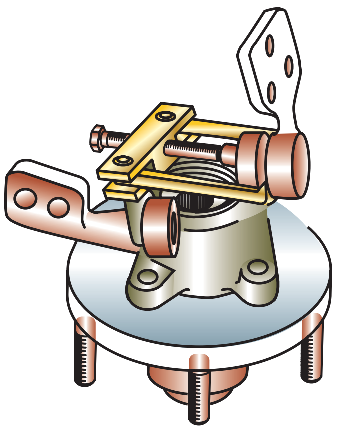


FIGURE 6-19 **Removing ball joint from the steering knuckle.**

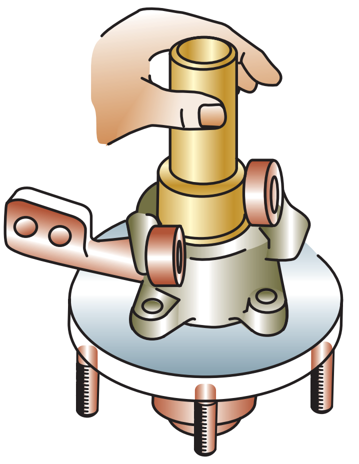


FIGURE 6-20 **Installing dust deflector in the steering knuckle.**

SPECIAL TOOLS

Ball joint puller

9. Pry the dust deflector from the steering knuckle with a large flat-blade screwdriver (Figure 6-18).
10. Use a puller to remove the ball joint from the steering knuckle (Figure 6-19). Check the ball joint and tie-rod end openings in the knuckle for wear and out-of-round. Replace the knuckle if these openings are worn or out-of-round.
11. Use the proper driving tool to reinstall the dust deflector in the steering knuckle (Figure 6-20).
12. Reverse steps 1 through 10 to reinstall the knuckle. Service or replace the wheel bearing as required. (Refer to Chapter 3 for wheel bearing service.) Torque all nuts to specifications and install cotter pins as required.

Front Steering Knuckle Replacement, Rear-Wheel-Drive Vehicle

Proceed as follows for steering knuckle replacement on short-and-long arm front suspension systems with the coil spring positioned between the lower control arm and the frame:

1. Remove the wheel cover and loosen the wheel nuts.
2. Lift the vehicle with a floor jack and place safety stands under the chassis so the front suspension drops downward. Lower the vehicle onto the safety stands and remove the floor jack.
3. Remove the front wheel, brake caliper, and the brake rotor and hub with the wheel bearings. Attach the brake caliper to a chassis component with a piece of wire. Do not allow the caliper to hang on the end of the brake hose.
4. Remove the outer tie-rod cotter pin and nut, and remove the outer tie-rod end from the steering arm.
5. Remove the cotter pins from the upper and lower ball joint nuts and loosen, but do not remove the nuts.

WARNING: During the knuckle replacement procedure, the floor jack supports the spring tension when the ball joints are disconnected from the knuckle. Do not lower the floor jack. Chain the coil spring to the lower control arm as a safety precaution.

SPECIAL TOOLS

Ball joint spreader tool

6. Support the lower control arm with a floor jack, and raise the floor jack until the spring tension is supported by the jack.

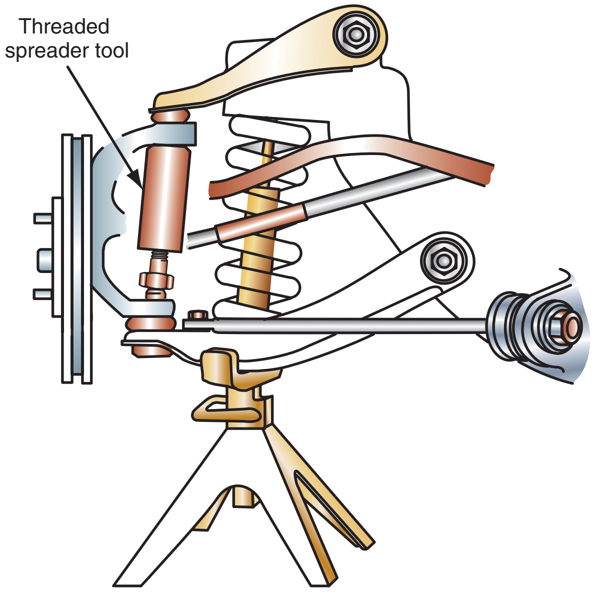


FIGURE 6-21 **Removing the lower ball joint from the steering knuckle.**

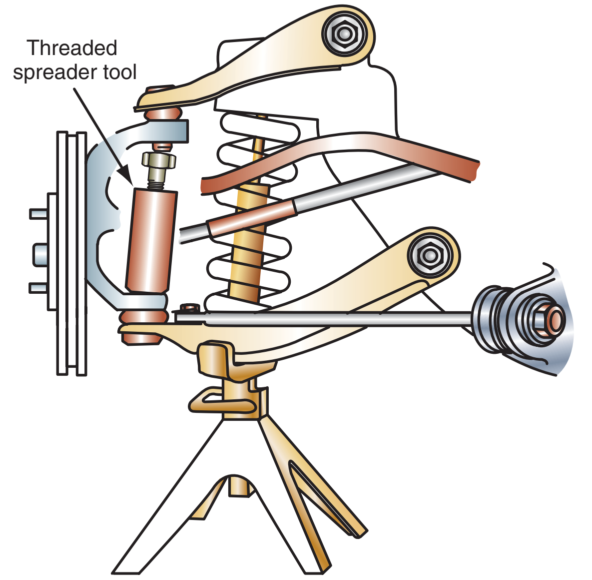


FIGURE 6-22 **Removing the upper ball joint from the steering knuckle.**

7. Remove both ball joint nuts, and remove the ball joint studs from the steering knuckle. A threaded spreader tool may be used to push the upper and lower ball joints from the knuckle (Figures 6-21 and 6-22).
8. Pull upward on the upper control arm to remove the upper ball joint stud from the knuckle. Remove the knuckle from the lower ball joint stud. Check the ball joint and tie-rod end openings in the knuckle for wear and out-of-round. Replace the knuckle if these conditions are present.
9. Reverse steps 1 through 8 to install the steering knuckle. Tighten the ball joint nuts and the outer tie-rod nut to the specified torque, and install the cotter pins in these nuts. Adjust the front wheel bearings, and tighten the wheel nuts to the specified torque.

Ball Joint Replacement

Results of Ball Joint Wear. Worn ball joints affect steering angles and cause reduced directional stability and excessive tire tread wear.

Ball Joint Removal and Replacement. Ball joints may be pressed, bolted (or riveted), or threaded into the control arms (Figure 6-23). The ball joint replacement procedure varies depending on the type of suspension and the method of ball joint attachment. Always follow the vehicle manufacturer's recommended ball joint replacement procedure in the service manual.

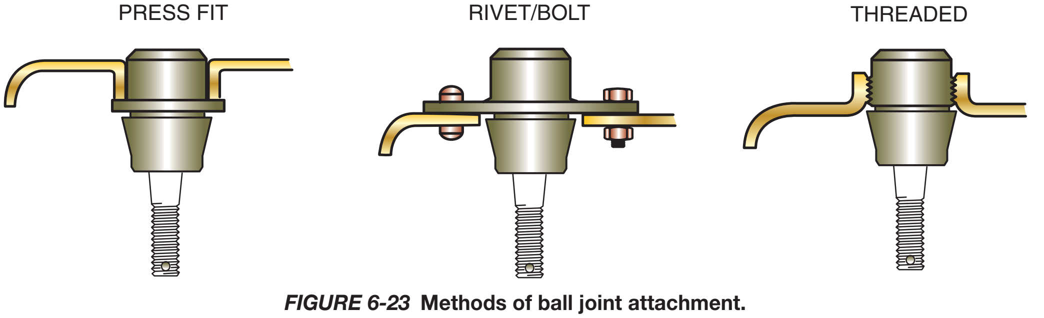


FIGURE 6-23 **Methods of ball joint attachment.**

SERVICE TIP: Some ball joints have a tapered stud, and a nut is threaded onto the top of this stud to retain the ball joint in the steering knuckle. Other ball joints have a straight stud, and a pinch bolt extends through the steering knuckle and a notch in the side of the ball joint stud to hold the ball joint in the steering knuckle.

SPECIAL TOOLS
Ball joint pressing tools

The following are typical steps that apply to all three methods of ball joint attachment:

1. Remove the wheel cover and loosen the wheel nuts.
2. Lift the vehicle with a floor jack and place safety stands under the chassis so the front suspension is allowed to drop downward. Lower the vehicle onto the safety stands and remove the floor jack.
3. Remove the wheel and place a floor jack under the outer end of the lower control arm. Operate the floor jack and raise the lower control arm until the ball joints are unloaded. Remove other components, such as the brake caliper, rotor, and drive axle, as required to gain access to the ball joints.
4. Remove the cotter pin in the ball joint or joints that requires replacement, and loosen, but do not remove the ball joint stud nuts.
5. Loosen the ball joint stud tapers in the steering knuckle. A threaded expansion tool is available for this purpose.
6. Remove the ball joint nut and lift the knuckle off the ball joint stud. Block or tie up the knuckle and hub assembly to access the ball joint.
7. If the ball joint is riveted to the control arm, drill and punch out the rivets, and bolt the new ball joint to the control arm (Figure 6-24).
8. If the ball joint is pressed into the lower control arm, remove the ball joint dust boot, and use a pressing tool to remove and replace the ball joint (Figures 6-25 and 6-26).
9. If the ball joint housing is threaded into the control arm, use the proper size socket to remove and install the ball joint. The replacement ball joint must be torqued to the manufacturer's specifications. If a minimum of 125 ft.-lbs. of torque cannot be obtained, the control arm threads are damaged and control arm replacement is necessary.
10. If the ball joint is bolted to the lower control arm, install the new ball joint and tighten the bolt and nuts to the specified torque (Figure 6-27).
11. Clean and inspect the ball joint stud tapered opening in the steering knuckle. If this opening is out-of-round or damaged, the knuckle must be replaced.
12. Check the fit of the ball joint stud in the steering knuckle opening. This stud should fit snugly in the opening and only the threads on the stud should extend through the knuckle. If the ball joint stud fits loosely in the knuckle tapered opening, either this opening is worn or the wrong ball joint has been supplied.

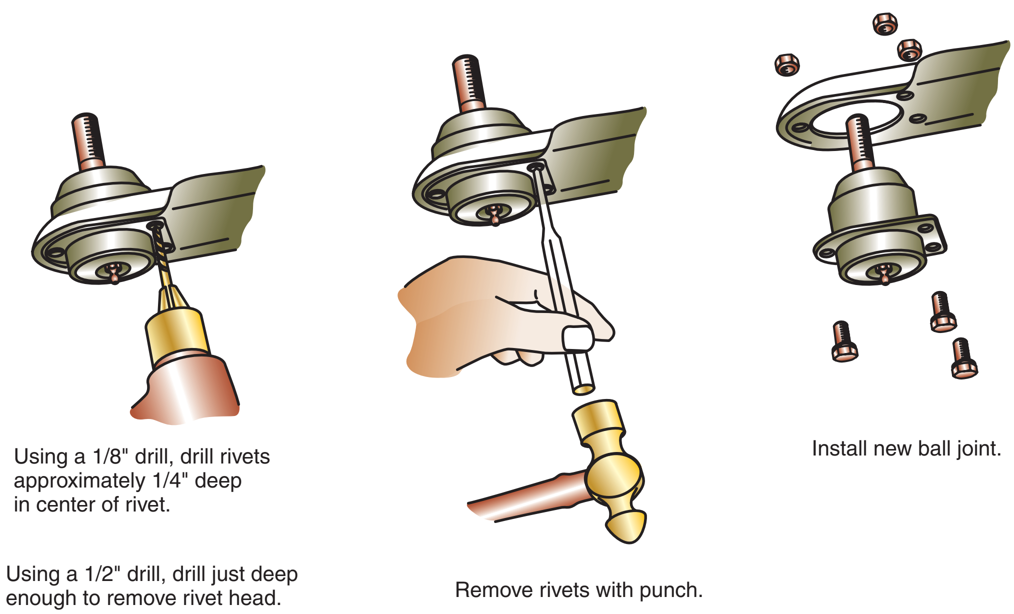


FIGURE 6-24 **Replacing the riveted ball joint.**

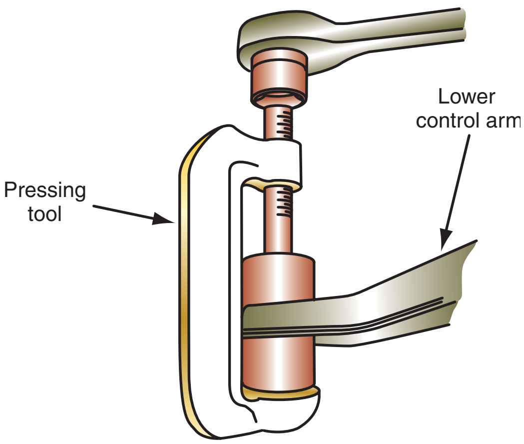


FIGURE 6-25 **Removing the pressed-in ball joint from the lower control arm.**

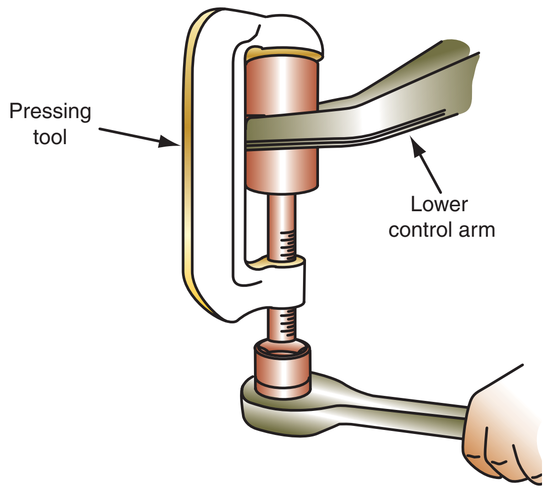


FIGURE 6-26 **Installing the pressed-in ball joint in the lower control arm.**

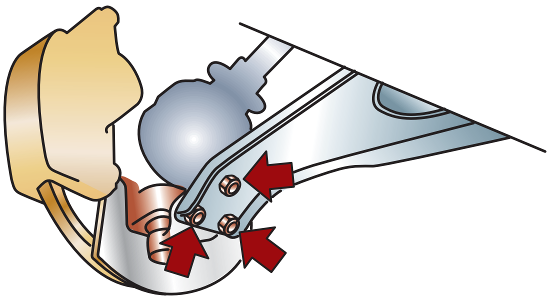


FIGURE 6-27 **Installing the ball joint retaining bolts and nuts in the lower control arm.**

13. Install the ball joint stud in the steering knuckle opening, making sure the stud is straight and centered. Install the stud nut and tighten this nut to the specified torque. Install a new cotter pin through the stud and nut. Do not loosen the nut to align the nut and stud openings.
14. Reassemble the components that were removed in step 3. Make sure the wheel nuts are tightened to the specified torque.
15. After ball joint replacement, the front suspension alignment should be checked.

CAUTION:
Never back off a ball joint stud nut to align the cotter pin openings in the nut and stud. This action may cause the ball joint stud to become loose in the opening where it is mounted. Always tighten the nut to the next hole to install the cotter pin.

Control Arm Diagnosis and Service

Control Arm Diagnosis and Replacement

Upper and lower control arms should be inspected for cracks, bent conditions, and worn bushings. If the control arm bushings are worn, steering is erratic, especially on irregular road surfaces. Worn control arm bushings may cause a rattling noise while driving on irregular road surfaces. Dry or worn control arm bushings may cause a squeaking noise on irregular road surfaces. Caster and camber angles on the front suspension are altered by worn upper and lower control arm bushings. Incorrect caster or camber angles may cause the vehicle to pull to one side. Tire wear may be excessive when the camber angle is not within specifications.

Lower Control Arm Replacement, MacPherson Strut Suspension

The upper or lower control arm removal and replacement procedure varies depending on the type of suspension. Always follow the recommended procedure in the vehicle manufacturer's service manual.

SPECIAL TOOLS
Tie-rod end puller

The following is a lower control arm replacement procedure for a MacPherson strut front suspension:

1. Remove the wheel cover and loosen the wheel nuts and drive axle nut.
2. Lift the front of the vehicle with a floor jack and place jack stands under the chassis. Lower the vehicle onto the safety stands and allow the front suspension to drop downward.
3. Remove the front wheel and the front fender apron seal (Figure 6-28). Remove the drive axle nut (Figure 6-29).
4. Remove the cotter pin and nut from the outer tie-rod end, and use a puller to remove this tie-rod end from the steering arm (Figure 6-30).
5. Remove the stabilizer brackets from the lower control arm (Figure 6-31).
6. Remove the lower ball joint nuts and bolts from the lower control arm (Figure 6-32).
7. Remove the drive axle from the axle hub (Figure 6-33), and secure the drive axle to a suspension component with a piece of wire (Figure 6-34). Do not allow the drive axle to hang downward.
8. Remove the two attaching bolts at the front side of the lower control arm (Figure 6-35).
9. Remove the bolt and nut on the rear side of the lower control arm (Figure 6-36), and remove the lower arm bushing stopper from the lower arm shaft.

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Reverse steps 1 through 9 to install the replacement control arm. Tighten all bolts and nuts to the specified torque, and install cotter pins as required.

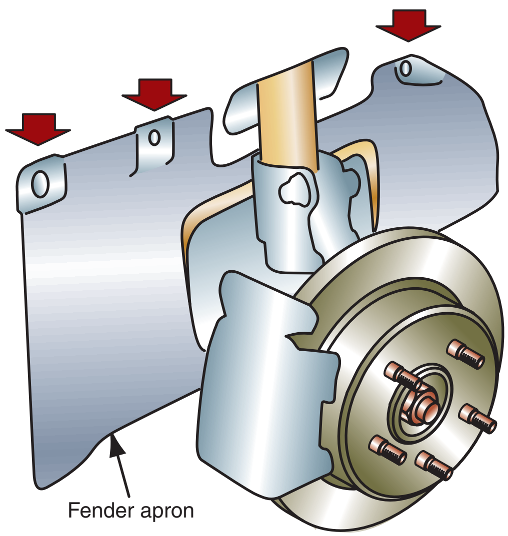

FIGURE 6-28 **Removing the front fender apron seal.**

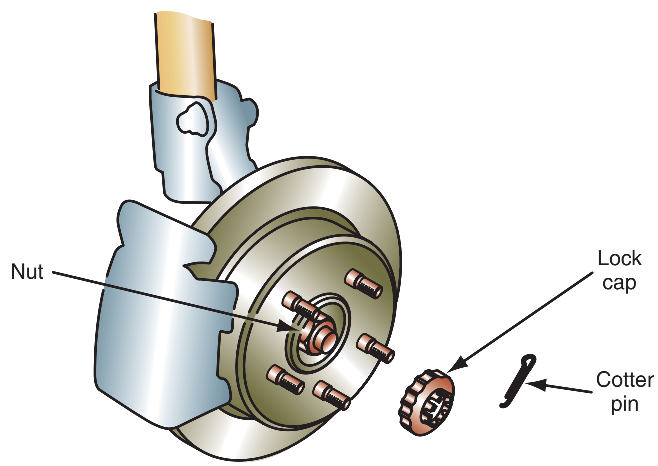

FIGURE 6-29 **Removing the drive axle cotter pin, lock, cap, and nut.**

FIGURE 6-30 **Removing the outer tie-rod end.**

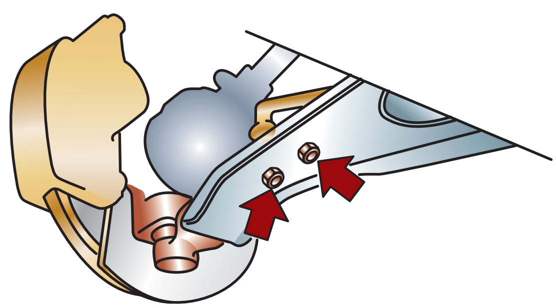

FIGURE 6-31 **Removing stabilizer brackets from the lower control arm.**

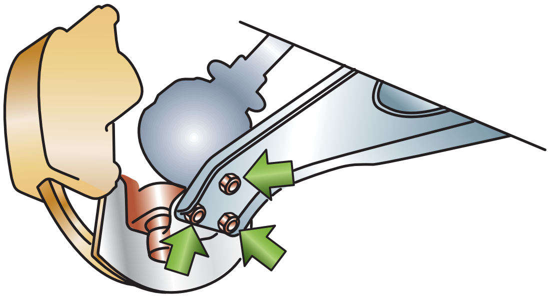

FIGURE 6-32 **Removing the lower ball joint bolts and nuts from the lower control arm.**

FIGURE 6-33 **Removing the drive axle from the axle hub.**

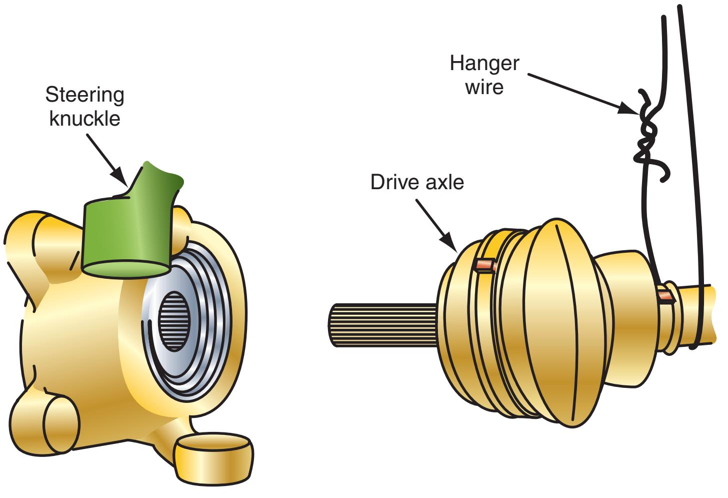

FIGURE 6-34 **Securing the drive axle with a piece of wire.**

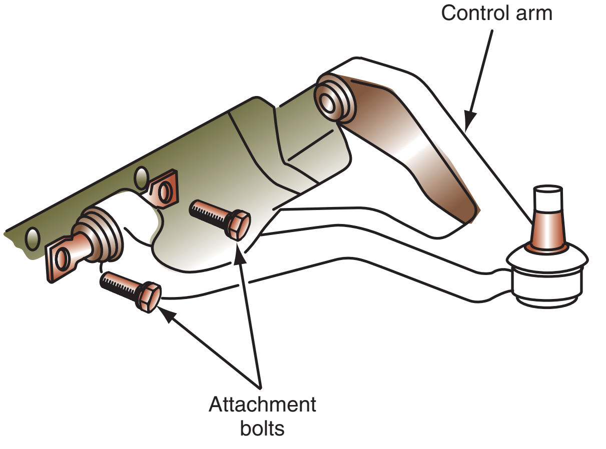

FIGURE 6-35 **Removing the bolts from the front side of the lower control arm.**

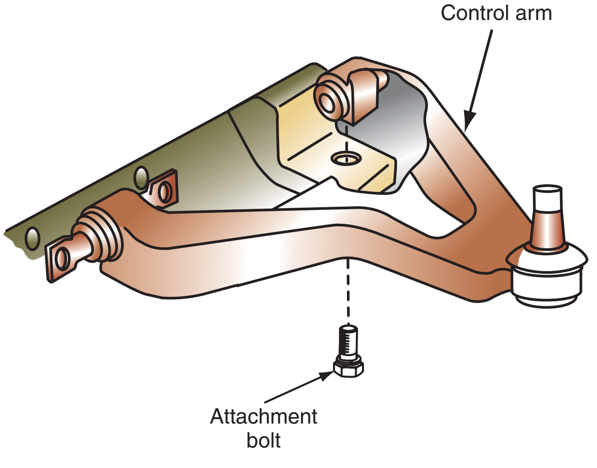

FIGURE 6-36 **Removing the bolt and nut from the rear side of the lower control arm.**

Lower Control Arm and Spring Replacement, Short-and-Long Arm Suspension

WARNING: During control arm and spring replacement, the coil spring tension is supported by a compressing tool or floor jack. Always follow the vehicle manufacturer's recommended control arm and spring replacement procedures very carefully. Serious personal injury or property damage may occur if the spring tension is released suddenly.

Broken coil springs may cause a rattling noise while driving on irregular road surfaces. Weak or broken coil springs also reduce curb riding height. A rattling noise while driving on road irregularities may also be caused by worn or broken spring insulators. Since weak or broken coil springs affect front suspension alignment angles, this problem may cause reduced directional stability, excessive tire wear, and harsh riding.

SPECIAL TOOLS
Spring compressing tool, short-and-long arm suspension

Follow this procedure when a lower control arm and/or spring is replaced on a vehicle with a short-and-long arm suspension system with the coil springs positioned between the lower control arm and the frame:

1. Lift the vehicle on a hoist until the tires are a short distance off the floor, and allow the front suspension to drop downward. An alternate method is to lift the vehicle with a floor jack, and then support the chassis securely on safety stands so the front suspension drops downward.
2. Disconnect the lower end of the shock absorber. On some applications, the shock absorber must be removed.
3. Disconnect the stabilizer bar from the lower control arm.
4. Install a spring compressor and turn the spring compressor bolt until the spring is compressed (Figure 6-37). Make sure all the spring tension is supported by thecompressing tool.
5. Place a floor jack under the lower control arm, and raise the jack until the control arm is raised and the rebound bumper is not making contact.
6. Remove the lower ball joint cotter pin and nut, and use a threaded expansion tool to loosen the lower ball joint stud.
7. Lower the floor jack very slowly to lower the control arm and coil spring.

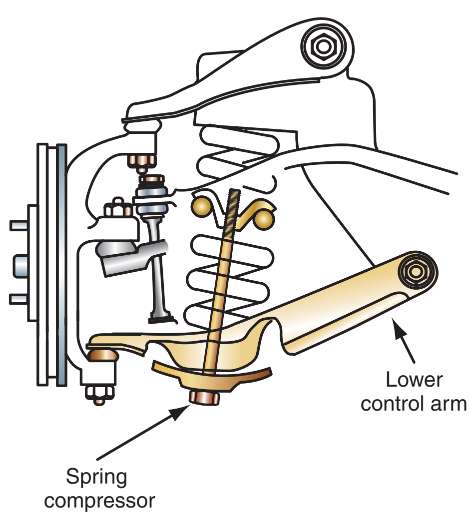

FIGURE 6-37 **Spring compressing tool installed on a spring in a short-and-long arm suspension system.**

8. Disconnect the lower control arm inner mounting bolts, and remove the lower control arm.
9. Rotate the compressing tool bolt to release the spring tension, and remove the spring from the control arm.
10. Inspect the lower control arm for a bent condition or cracks. If either of these conditions is present, replace the control arm. Visually inspect all control arm bushings. Loose or worn bushings must be replaced. Visually inspect upper and lower spring insulators for cracks and wear, and inspect the spring seat areas in the chassis and lower control arm. Worn or cracked spring insulators must be replaced.
11. Reverse steps 1 through 9 to install the lower control arm. Be sure the coil spring and insulators are properly seated in the lower control arm and in the upper spring seat.

Note: See Chapter 5 for strut and spring service.

Upper Control Arm Removal and Replacement, Short-and-Long Arm Suspension System

Proceed as follows when replacing an upper control arm on a short-and-long arm suspension system with the front coil springs located between the lower control arm and the frame:

1. Remove the wheel cover and loosen the wheel nuts.
2. Lift the vehicle with a floor jack and install safety stands under the chassis. Lower the vehicle onto the safety stands so the front suspension drops downward.
3. Remove the front wheel and tire.
4. Place a floor jack under the lower control arm and raise this arm. Make sure the rebound bumper is not making contact.
5. Remove the cotter pin and loosen, but do not remove the upper ball joint nut.
6. Use a threaded expansion tool to loosen the ball joint stud in the control arm. Make sure the floor jack is supporting the spring tension.
7. Remove the ball joint nut and the inner control arm mounting bolts. If shims are located on the inner control arm mounting bolts, note the shim position.
8. Remove the control arm from the chassis.
9. Visually inspect the upper control arm for a bent or cracked condition. Inspect the control arm bushing openings for wear, and replace the control arm if it is bent, cracked, or worn in the bushing areas. Inspect the control arm shaft and bushings for wear, and replace all worn parts (Figure 6-38).
10. Install the control arm and place the original number of shims on the inner mounting bolts. Tighten these bolts to the manufacturer's specifications.

CAUTION:
Since the floor jack is supporting the spring tension, do not lower the floor jack until the ball joint is reconnected and the ball joint nut is tightened to the specified torque.

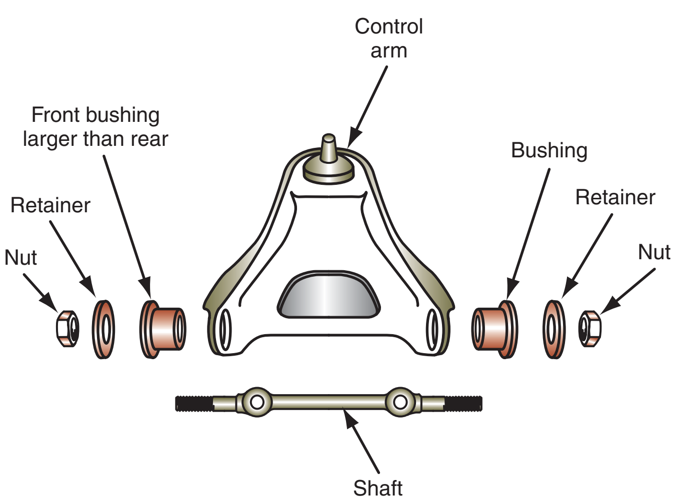

FIGURE 6-38 **Upper control arm components.**

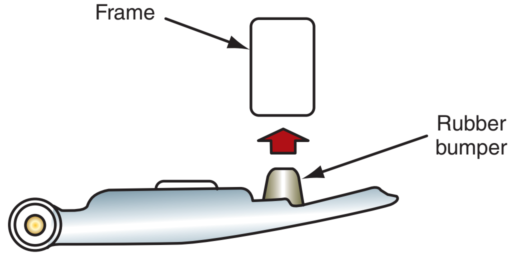

FIGURE 6-39 **Rebound bumper.**

SERVICE TIP: Excessively worn rebound bumpers indicate worn-out shock absorbers, reduced curb riding height, or driving continually on irregular road surfaces.

11. Install the ball joint stud in the steering knuckle, and tighten the stud nut to the specified torque.
12. Install the upper ball joint cotter pin and the front wheel. Tighten the wheel nuts to the specified torque.

The front suspension alignment angles should be checked after upper control arm replacement.

Rebound Bumpers

Rebound bumpers limit the maximum lower control arm movement to prevent coil spring bottoming. Rebound bumpers may be called strikeout bumpers.

Rebound bumpers are usually bolted to the lower control arm or to the chassis. Inspect the rebound bumpers for cracks, wear, and flattened conditions (Figure 6-39). Damaged rebound bumpers may be caused by sagged springs and insufficient curb riding height or worn-out shock absorbers and struts. If the rebound bumpers must be replaced, remove the mounting bolts and the bumper. Install the new bumper and tighten the mounting bolts to the specified torque.

Front Lower Control Arm Bushing Removal and Replacement

SPECIAL TOOLS
Control arm bushing removal, replacement, and flaring tools

All suspension bushings should be checked periodically for wear, looseness, and deterioration. These bushings are important for providing quiet suspension operation and preventing the transmission of suspension vibration to the chassis and passenger compartment. When a bushing is contained in a steel sleeve, press only on the outer sleeve during the removal and replacement procedure. The control arm bushing removal and replacement procedure varies depending on the type of suspension system. Always follow the vehicle manufacturer's recommended procedure in the service manual. Special bushing removal and replacement tools are required for control arm bushing replacement. A front control arm bushing removal tool and spacer is used to remove the control arm bushing (Figure 6-40). The spacer is installed between the bushing support lugs to prevent distorting these lugs during the bushing removal process.

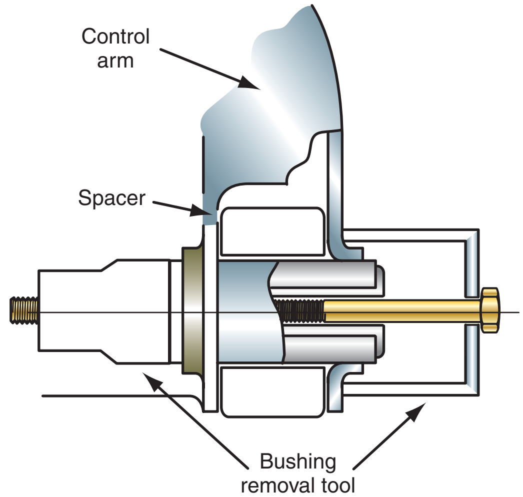

FIGURE 6-40 **Removing the front control arm bushing.**

A different tool is required to install the new front control arm bushing (Figure 6-41). The same spacer that is used during the bushing removal is installed between the bushing lugs during bushing installation.

After the front control arm bushing is installed, a bushing flaring tool is used to flare the bushing (Figure 6-42). Notice that a spacer is installed between the bushing lugs during the flaring process. Flaring retains the bushing securely (Figure 6-43).

The rear control arm bushing is replaced with the same procedure as the front control arm bushing. Some of the same special tools are used for rear control arm bushing replacement (Figures 6-44 and 6-45).

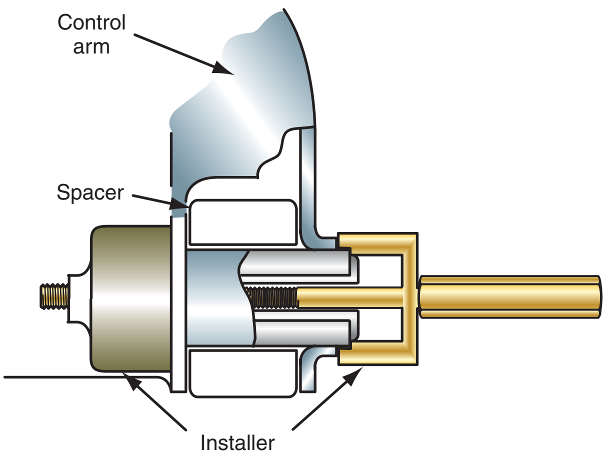

FIGURE 6-41 **Installing the front control arm bushing.**

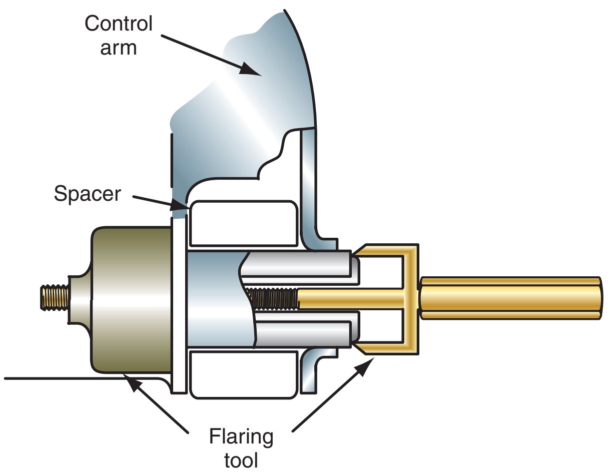

FIGURE 6-42 **Flaring the front control arm bushing.**

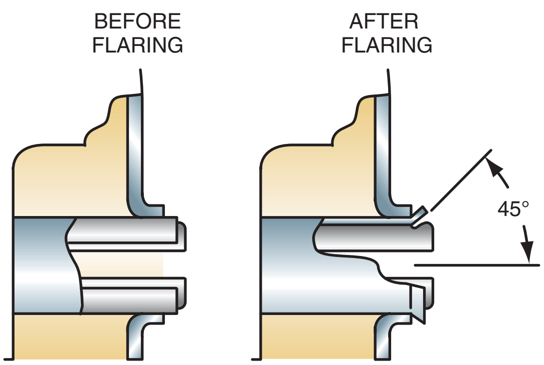

FIGURE 6-43 **Front control arm bushing after flaring.**

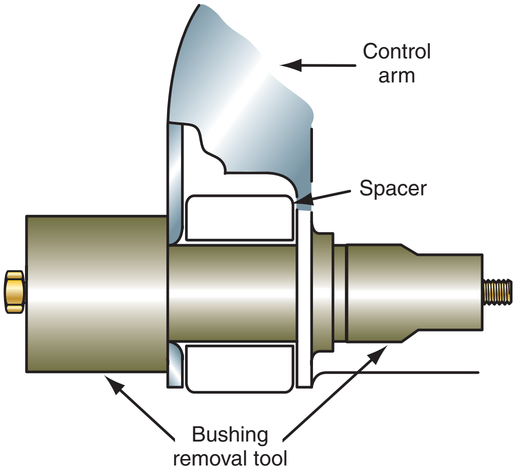

FIGURE 6-44 **Removing the rear control arm bushing.**

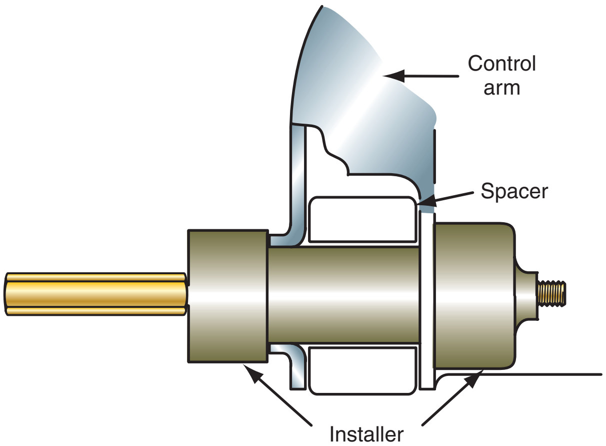

FIGURE 6-45 **Installing the rear control arm bushing.**

Stabilizer Bar Diagnosis and Replacement

A **stabilizer bar** may be referred to as a sway bar. It reduces body sway when one wheel strikes a road irregularity.

Worn **stabilizer bar** mounting bushings, grommets, or mounting bolts cause a rattling noise as the vehicle is driven on irregular road surfaces. A weak stabilizer bar or worn bushings and grommets cause harsh riding and excessive body sway while driving on irregular road surfaces. Worn or very dry stabilizer bar bushings may cause a squeaking noise on irregular road surfaces. All stabilizer bar components should be visually inspected for wear. Stabilizer bar removal and replacement procedures vary depending on the vehicle. Always follow the vehicle manufacturer's recommended procedure in the service manual.

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The following is a typical stabilizer bar removal and replacement procedure:

1. Lift the vehicle on a hoist and allow both sides of the front suspension to drop downward as the vehicle chassis is supported on the hoist.
2. Remove the mounting bolts at the outer ends of the stabilizer bar and remove the bushings, grommets, brackets, or spacers (Figure 6-46).
3. Remove the mounting bolts in the center area of the stabilizer bar.
4. Remove the stabilizer bar from the chassis.
5. Visually inspect all stabilizer bar components, such as bushings, bolts, and spacer sleeves. Replace the stabilizer bar, grommets, bushings, brackets, or spacers as required. Split bushings may be removed over the stabilizer bar. Bushings that are not split must be pulled from the bar.
6. Reverse steps 2 through 4 to install the stabilizer bar. Make sure all stabilizer bar components are installed in the original position, and tighten all fasteners to the specified torque.

Some vehicle manufacturers specify that stabilizer bars must have equal distances between the outer bar ends and the lower control arms. Always refer to the manufacturer's recommended measurement procedure. If this measurement is required, adjust the nut on the outer stabilizer bar mounting bolt until equal distances are obtained between the outer bar ends and the lower control arms. Worn grommets cause these distances to be unequal.

Strut Rod Diagnosis and Replacement

A **strut rod** prevents fore-and-aft lower control arm movement.

Some front suspension systems have a **strut rod** connected from the lower control arm to the frame. Rubber grommets isolate the rod from the chassis components. Worn strut rod grommets may allow the lower control arm to move rearward or forward. This movement changes the caster angle, which may affect steering quality and cause the vehicle to pull to one side. A bent strut rod also causes steering pull. Worn strut rod grommets or loose mounting bolts cause a rattling noise while driving on irregular road surfaces. Inspect the strut rod grommets

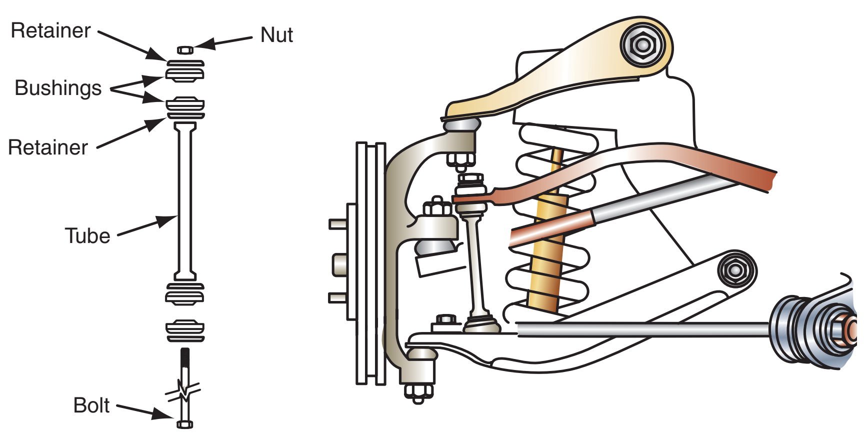

FIGURE 6-46 **Stabilizer bar components.**

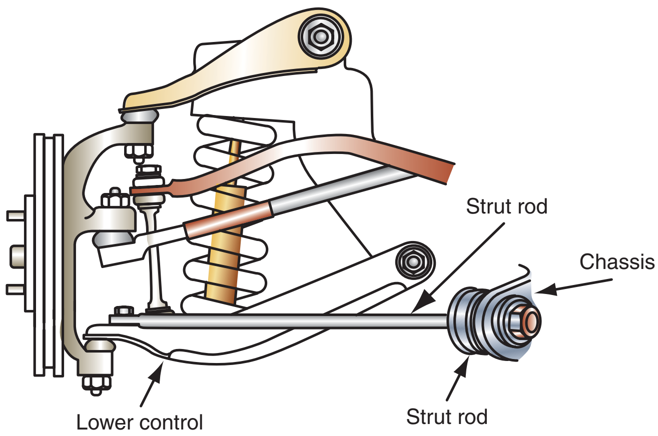

FIGURE 6-47 **Strut rod.**

visually for wear and deterioration. With the vehicle lifted on a hoist, grasp the strut rod firmly and apply vertical and horizontal force to check the rod and grommets for movement. Worn grommets must be replaced. If a strut rod is bent, replace the rod.

Follow these steps for strut rod replacement:

1. Lift the vehicle on a hoist.
2. Remove the strut rod nut from the front end of the rod.
3. Remove the strut rod bolts from the lower control arm.
4. Pull the strut rod rearward to remove the rod (Figure 6-47).
5. Remove the bushings from the opening in the chassis.
6. Visually inspect the strut rod, bushings, washers, and retaining bolts. Replace all worn parts. Reverse steps 1 through 5 to reinstall the strut rod. Tighten the strut rod nut and bolts to the specified torque.

Since strut rod and bushing conditions affect front suspension alignment, check front suspension alignment after strut rod service.

Front Leaf Spring Inspection and Replacement

Front leaf springs are used in some truck suspension systems. These springs are mounted longitudinally with a spring on each side of the suspension. Many leaf springs have plastic silencers between the spring leafs. If these silencers are worn out, creaking and squawking noises will be heard when the vehicle is driven over road irregularities at low speeds.

When the silencers require checking or replacement, lift the vehicle with a floor jack and support the frame on safety stands so the suspension hangs downward. With the vehicle weight no longer applied to the springs, the spring leafs may be pried apart with a pry bar to remove and replace the silencers. On some leaf springs, the clamps must be removed to replace the silencers.

Leaf springs should be inspected for a sagged condition, which causes the curb riding height to be less than specified. Leaf springs should also be visually inspected for broken leafs, broken center bolts, and worn shackles or bushings. Weak or broken leaf springs affect front suspension alignment angles and cause excessive tire tread wear, reduced directional stability, and harsh riding. A rattling noise while driving on irregular road surfaces may be caused by worn shackles or bushings. A broken center bolt usually allows one side of the front suspension to move rearward in relation to the other side. This action may cause steering pull to one side. Worn shackles and bushings lower curb riding height and cause a rattling noise on road irregularities.

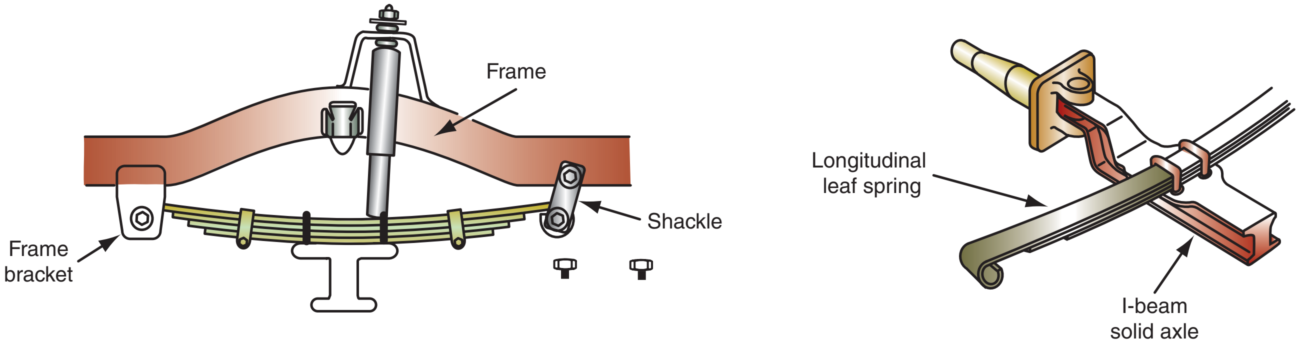

FIGURE 6-48 **Front leaf spring.**

The following is a typical front leaf spring replacement procedure:

1. Lift the front end of the vehicle with a floor jack under the front axle and place safety stands under the frame. Lower the vehicle weight onto the safety stands, but leave the floor jack under the front axle to support some of the front suspension weight.
2. Remove the nuts from the spring U-bolts, and remove the U-bolts and lower spring plate. If the spring plate is attached to the shock absorber, this plate may be left on the shock absorber and moved out of the way. If shims are positioned between the spring plate and the front axle, be sure to note the position and the number of shims. These shims must be reinstalled in their original position because they set the front wheel caster angle.
3. Be sure the floor jack is lowered enough to relieve the vehicle weight from the springs.
4. Remove the front shackle assembly.
5. Remove the rear spring mounting bolt, and remove the spring from the chassis (Figure 6-48).
6. Check all the spring hangers, bolts, bushings, and shackle plates for wear, and replace as required. Springs with broken or sagged leafs are usually sent to a spring rebuilding shop for repair.
7. Check the spring center bolt to be sure it is not broken.
8. Reverse steps 1 through 5 to install the front springs. Tighten all bolts to the manufacturer's specifications.

Removing and Replacing Longitudinally Mounted Torsion Bars

Worn torsion bar components, such as pivot cushion bushings and control arm bushings, result in harsh riding and suspension noise when driving on road irregularities. A worn torsion bar hex and anchor may cause a rattling noise while driving on irregular road surfaces. Weak torsion bars or those with worn bushings or anchors cause reduced curb riding height, which may result in reduced directional stability and excessive tire tread wear. Always follow the vehicle manufacturer's recommended procedure in the service manual for torsion bar removal and replacement.

The following is a typical torsion bar removal and replacement procedure:

WARNING: Some torsion bar front suspension systems on sport utility vehicles (SUVs) are combined with an air suspension system. When servicing these systems, the air suspension switch in the rear jack storage area must be shut off before performing any suspension service or hoisting, jacking, or towing the vehicle. If this procedure is not followed, personal injury and vehicle damage may occur.

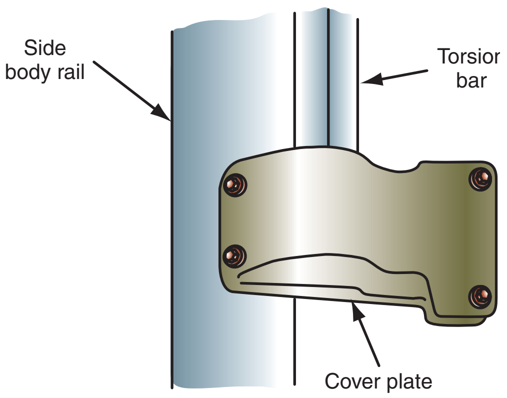

FIGURE 6-49 **Torsion bar cover plate.**

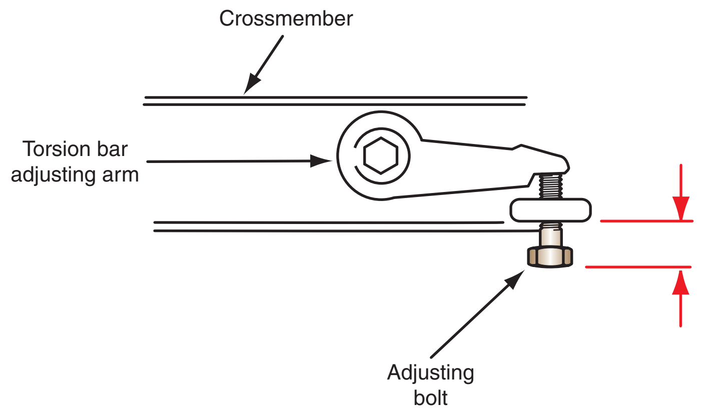

FIGURE 6-50 **Measuring the torsion bar adjusting bolt position.**

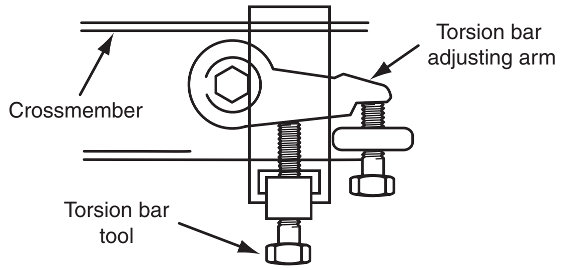

FIGURE 6-51 **Torsion bar tool and adapters.**

1. Raise the vehicle on a lift with the tires supported on the lift.
2. Remove the torsion bar cover plate bolts and the cover plate (Figure 6-49).
3. Measure and record the distance from the lip on the head of the torsion bar adjusting bolt to the casting surface this bolt is threaded into (Figure 6-50). When reinstalled, this bolt must be adjusted to this same measurement.
4. Install the torsion bar tool and adapters (Figure 6-51). Tighten this tool until the torsion bar adjuster lifts off the adjustment bolt.
5. Remove the torsion bar adjustment bolt and nut.
6. Loosen the torsion bar tool to remove all the tension from the torsion bar (Figure 6-52).
7. Use the end of a screwdriver to place matching alignment marks on the torsion bar and the adjuster so these components may be reassembled in the same position. Remove the torsion bar insulator. Pull the torsion bar to the rear to remove this bar from the lower control arm.
8. Position the torsion bar in the lower control arm.
9. Install the torsion bar adjuster on the torsion bar with the alignment marks properly aligned (Figure 6-53).

CAUTION:
The torsion bar adjusting bolt is coated with a dry adhesive. This bolt must be replaced if it is backed off or removed. Failure to follow this procedure may cause the bolt to loosen during operation, resulting in improper wheel alignment, reduced steering control, increased tire wear, and reduced ride quality.

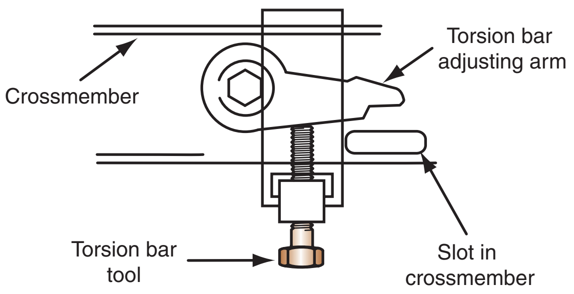

FIGURE 6-52 **Loosening the torsion bar tool.**

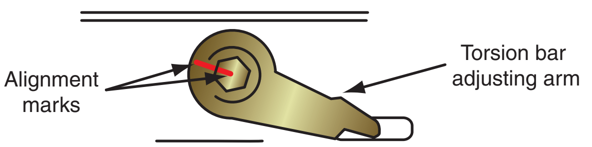

FIGURE 6-53 **Alignment marks placed on the torsion bar and adjuster.**

10. Install the torsion bar tool and adapters. Tighten the torsion bar tool until a new adjustment bolt can be installed. Tighten this bolt until the measurement obtained in step 3 is obtained between the head of the bolt and the casting the bolt is threaded into.
11. Install the torsion bar cover plate, and tighten the plate retaining bolts to the specified torque.
12. Measure the suspension riding height as explained previously this chapter. If the suspension riding height is not within specifications, adjust the torsion bar adjusting bolt to obtain the specified riding height.

TABLE 6-1 **FRONT SUSPENSION DIAGNOSIS**

Problem	Symptoms	Possible Causes
Low riding height	Harsh ride quality, worn strikeout bumpers	Weak springs, worn control arm bushings, bent control arms, improper torsion bar adjustment
Steering wander, excessive edge wear on front tires	Erratic steering control when driving straight ahead	Worn ball joints, worn suspension or steering components, improper wheel alignment
Suspension noise	Rattling or squeaking noise when driving on road irregularities	Worn or dry stabilizer bar links and bushings, worn shock absorber or strut rod bushings
Improper steering control	Steering pull to the left or right when driving straight ahead	Improper wheel alignment, worn control arm bushings, bent control arms
Improper steering control while braking	Steering pull to the left or right only when braking	Worn strut rod bushings, loose strut rod mounting, worn lower control arm bushings
Leaf spring noise	Squeaking noise when driving on road irregularities	Worn silencers between the spring leafs

CASE STUDY

A customer complained about steering pull to the left while braking on a 2009 Chrysler 300. The technician questioned the customer about other symptoms, but the customer stated that the steering did not pull while driving, and the car had no other problems. Further questioning of the customer revealed that extensive brake work had been done in an attempt to correct the problem. The front brake pads had been replaced and the front brake rotors had been turned.

While performing a road test, the technician discovered the car had a definite pull to the left while braking, but the steering was normal while driving. During the road test, no other problems were evident. The technician removed the front wheels and brake rotors. A careful examination of the brake linings and rotor surfaces indicated these components were in excellent condition. The technician checked the rotor surfaces to be sure they were both in the same condition. The pistons in both front calipers moved freely. An inspection of the brake lines and hoses did not reveal any visible problems, and a pressure check at each front brake caliper indicated equal pressures at both front wheels during a brake application.

Next, the technician made a visual inspection of the steering and suspension components and discovered a worn, loose left front tension rod bushing. This tension rod was replaced, and the strut rod nut tightened to the specified torque. A road test of the car indicated no steering pull during brake application.

Terms to Know

Ball joint vertical movement
Ball joint wear indicator
Camber angles
Caster angles
Curb riding height
Directional stability
Rebound bumpers
Stabilizer bar
Steering effort
Strut rod

ASE-Style Review Questions

1. While discussing curb riding height:
   Technician A says worn control arm bushings reduce curb riding height.
   Technician B says incorrect curb riding height affects most other front suspension angles.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

2. The shoulder on the ball joint grease fitting is inside the ball joint cover:
   Technician A says the ball joint should be replaced.
   Technician B says a longer grease fitting should be installed.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

3. While discussing ball joint unloading on a short-and-long arm suspension system with the coil springs between the lower control arm and the chassis:
   Technician A says a steel spacer should be installed under the upper control arm.
   Technician B says a floor jack should be placed under the lower control arm to unload the ball joints.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

4. While discussing ball joint radial measurement:
   Technician A says the dial indicator should be positioned against the top of the ball joint stud.
   Technician B says the front wheel bearing adjustment does not affect the ball joint radial measurement.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

5. While discussing ball joint installation:
   Technician A says the ball joint nut may be backed off to install the cotter pin.
   Technician B says only the ball joint threads should extend above the opening in the steering knuckle.
   Who is correct?
   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

6. When installing a new threaded ball joint in a lower control arm, the technician can only torque the ball joint to 90 ft.-lbs. The necessary repair for this problem is to:
   A. Weld the ball joint into the control arm.
   B. Place Loctite on the ball joint threads.
   C. Replace the lower control arm.
   D. Install a larger diameter ball joint.

7. All of these defects could result in worn-out rebound bumpers EXCEPT:
   A. Sagged springs.
   B. Worn-out shock absorbers.
   C. Continual driving on rough roads.
   D. Curb riding height more than specified.

8. When removing and replacing control arm bushings:
   A. If the bushing is contained in a steel sleeve, press on the rubber bushing.
   B. A spacer should be installed between the control arm support lugs during bushing removal and installation.
   C. The same tool is used for bushing removal and replacement.
   D. Bushing flaring is necessary to expand the bushing.

9. A car experiences excessive body sway when cornering, but there is no abnormal noise in the suspension. The most likely cause of this problem is:
   A. Stabilizer bar bushing is missing.
   B. A weak stabilizer bar.
   C. Stabilizer bar grommets are worn out.
   D. A broken stabilizer bar.

10. The steering on a vehicle pulls to the left while driving straight ahead. The most likely cause of this problem is:
    A. The left front strut rod is bent.
    B. The left lower ball joint is worn.
    C. Worn front stabilizer bushings on the left side.
    D. Reduced curb riding height on both sides of the front suspension.

ASE CHALLENGE QUESTIONS

1. The customer says her 2009 Silverado truck with front torsion bar suspension pulls to the left. A cursory check of the vehicle shows that the right front tire height is too low. The next step to diagnose the condition would be:
   A. Check the ball joints.
   B. Check the torsion bar.
   C. Check the strut rod bushings.
   D. Check the stabilizer bar bushings.

2. A customer says her front-wheel-drive car has a steering wander problem on irregular road surfaces. All of the following could cause this problem EXCEPT:
   A. Worn stabilizer bar bushings.
   B. Worn ball joints.
   C. Worn strut rod bushings.
   D. Worn tie-rod ends.

3. While diagnosing a customer's complaint of steering instability on a MacPherson strut front suspension with wear indicator-type ball joints, an inspection of the ball joints shows the grease fittings to be solid.

   Technician A says no movement of the fitting means the ball joint is good.

   Technician B says ball joint wear may not be apparent with the weight on the joint.

   Who is correct?

A. A only	C. Both A and B
B. B only	D. Neither A nor B

4. A customer says her rear-wheel-drive car has excessive body sway while cornering. In diagnosing this problem, which of the following components should you check first?
   A. Control arm bushings.
   B. Strut rod bushings.
   C. Stabilizer bar bushings.
   D. Shock absorber bushings.

5. *Technician A* says a bent strut rod can cause a car to pull to one side.

   Technician B says a deteriorated strut rod bushing can cause steering and braking problems.

   Who is correct?

A. A only	C. Both A and B
B. B only	D. Neither A nor B

Name ______________________________ Date ____________________

Measure Lower Ball Joint Vertical and HORIZONTAL Movement, Short-and-Long Arm Suspension Systems

Upon completion of this job sheet, you should be able to measure ball joint wear and determine the necessary ball joint service.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task C-5. Remove, inspect, and install upper and/or lower ball joints.

Tools and Materials

Ball joint dial indicator
Floor jack
Safety stands

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ____________________________
VIN ______________________________ Engine type and size _______________________

Procedure — Task Completed

1. Raise the front of the vehicle with a floor jack lift pad positioned on the specified lifting point. ☐

2. Install safety stands near the outer ends of the lower control arms. Lower the floor jack so the control arms are supported on the safety stands. Remove the floor jack. ☐

3. Attach a dial indicator for ball joint measurement to the lower control arm, and position the dial indicator stem against the lower end of the steering knuckle next to the ball joint retaining nut if the suspension has a lower compression-loaded ball joint. When the suspension has a tension-loaded ball joint, place the indicator stem against the top of the ball joint stud.

   Type of ball joint

   Dial indicator stem position

4. Preload the dial indicator stem 0.250 in. (6.35 mm), and zero the dial indicator.

   Is the dial indicator preloaded and placed in the zero position? ☐ Yes ☐ No

   Instructor check ____

5. Place a pry bar under the front tire and lift straight upward on the pry bar while a coworker observes the dial indicator. ☐

6. Compare the reading on the dial indicator with the vehicle manufacturer's specifications. If the vertical ball joint movement exceeds specifications, replace the ball joint. ☐

Task Completed

Specified ball joint vertical movement

Actual ball joint vertical movement

Necessary ball joint service

☐ 7. Be sure the front wheel bearings are properly adjusted.

8. Attach the dial indicator to the lower control arm, and position the dial indicator against the inner edge of the wheel rim. Preload the dial indicator 0.250 in. (6.35 mm) and place the dial in the zero position.

Is the dial indicator preloaded and placed in the zero position? ☐ Yes ☐ No

Instructor check ______________________________

☐ 9. Grasp the tire at the top and bottom, and try to rock the tire inward and outward while a coworker observes the dial indicator.

☐ 10. Compare the reading on the dial indicator to the vehicle manufacturer's specifications. If the horizontal ball joint movement exceeds specifications, replace the ball joint.

Specified ball joint horizontal movement

Actual ball joint horizontal movement

☐ 11. Repeat the measurements in steps 3 through 10 on the opposite side of the front suspension.

12. Based on your ball joint measurements, state all the necessary ball joint service and explain the reasons for your diagnosis.

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Instructor's Response ______________________________

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Name ______________________________ Date ____________________

Ball Joint Replacement

Upon completion of this job sheet, you should be able to remove and replace ball joints.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task C-5. Remove, inspect, and install upper and/or lower ball joints.

Tools and Materials

Floor jack	Ball joint loosening tool
Safety stands	Torque wrench

Describe the Vehicle Being Worked On:

Year ________ Make ________________ Model ______________________

VIN ________________________ Engine type and size __________________

Procedure — Task Completed

1. Remove the wheel cover and loosen the wheel nuts. ☐
2. Lift the vehicle with a floor jack and place safety stands under the chassis so the front suspension is allowed to drop downward. Lower the vehicle onto the safety stands and remove the floor jack. ☐
3. Remove the wheel and place a floor jack under the outer end of the lower control arm. Operate the floor jack and raise the lower control arm until the ball joints are unloaded.

   Are the ball joints properly unloaded? ☐ Yes ☐ No

   Instructor check ____
4. Remove other components, such as the brake caliper, rotor, and drive axle, as required to gain access to the ball joints. ☐
5. Remove the cotter pin in the ball joint or joints that require replacement, and loosen, but do not remove, the ball joint stud nuts.

   Is the ball joint stud nut loosened? ☐ Yes ☐ No

   Instructor check ____
6. Loosen the ball joint stud tapers in the steering knuckle. A threaded expansion tool is available for this purpose.

   Are the ball joint stud tapers loosened? ☐ Yes ☐ No

   Instructor check ____
7. Remove the ball joint nut and lift the knuckle off the ball joint stud. Block or tie up the knuckle and hub assembly to access the ball joint. ☐

Task Completed

☐ 8. If the ball joint is riveted to the control arm, drill and punch out the rivets and bolt the new ball joint to the control arm.

☐ 9. If the ball joint is pressed into the lower control arm, remove the ball joint dust boot and use a pressing tool to remove and replace the ball joint.

10. If the ball joint housing is threaded into the control arm, use the proper size socket to remove and install the ball joint. The replacement ball joint must be torqued to the manufacturer's specifications. If a minimum of 125 ft.-lbs. of torque cannot be obtained, the control arm threads are damaged and control arm replacement is necessary.

Ball joint torque, threaded ball joint ____________________

Control arm condition, threaded ball joint: ☐ Satisfactory ☐ Unsatisfactory

11. If the ball joint is bolted to the lower control arm, install the new ball joint and tighten the bolt and nuts to the specified torque.

Ball joint bolt torque ____________________

☐ 12. Clean and inspect the ball joint stud tapered opening in the steering knuckle. If this opening is out-of-round or damaged, the knuckle must be replaced.

Condition of ball joint stud opening in the steering knuckle:

☐ Satisfactory ☐ Unsatisfactory

13. Check the fit of the ball joint stud in the steering knuckle opening. This stud should fit snugly in the opening and only the threads on the stud should extend through the knuckle. If the ball joint stud fits loosely in the knuckle tapered opening, either this opening is worn or the wrong ball joint has been supplied.

Ball joint stud smooth tapered area appearing above steering knuckle surface:

☐ Yes ☐ No

If the answer to this question is yes, state the necessary repairs and explain the reason for your diagnosis.

____

____

CAUTION: Never back off a ball joint stud to align the cotter pin openings in the nut and stud. This may cause the ball joint stud to loosen, resulting in a suspension failure. Always tighten the nut to the next hole to install the cotter pin.

Ball joint stud fit in the steering knuckle opening:

☐ Satisfactory ☐ Unsatisfactory

If the ball joint stud fit in the steering knuckle opening is unsatisfactory, state the necessary repairs and explain the reason for your diagnosis.

____

____

14. Install the ball joint stud in the steering knuckle opening, making sure the stud is straight and centered. Install the stud nut and tighten this nut to the specified torque. Install a new cotter pin through the stud and nut. Do not loosen the nut to align the nut and stud openings.

Specified ball joint nut torque ______________________

Actual ball joint nut torque ______________________

Is a new cotter pin properly installed? ☐ Yes ☐ No

Instructor check ______________________

15. Reassemble the components that were removed in step 4. Make sure the wheel nuts are tightened to the specified torque.

Specified wheel nut torque ______________________

Actual wheel nut torque ______________________

Instructor's Response ______________________

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Name ______________________________ Date ____________________

Steering Knuckle Removal, MacPherson Strut Front Suspension

Upon completion of this job sheet, you should be able to remove the steering knuckle and determine knuckle condition on McPherson strut front suspension systems.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task C-6. Remove, inspect, and install steering Knuckle assemblies.

Tools and Materials

Floor jack
Safety stands
Tire-rod end puller
Torque wrench
Driving tools

Procedure

Task Completed

1. Remove the wheel cover and loosen the front wheel nuts and the drive axle nut. ☐
2. Lift the vehicle chassis on a hoist and allow the front suspension to drop downward. Remove the front wheel, brake caliper, brake rotor, and drive axle nut. Tie the brake caliper to a suspension component; do not allow the caliper to hang on the end of the brake hose.

   Is the vehicle weight supported on hoist with front suspension dropped downward?
   ☐ Yes ☐ No

   Instructor check ____
3. Remove the inner end of the drive axle from the transaxle with a pulling or prying action. On some Chrysler products, the differential cover must be removed and axle circlips compressed prior to drive axle removal from the transaxle.

   Is the inner end of drive axle removed from transaxle? ☐ Yes ☐ No

   Instructor check ____
4. Remove the outer end of the drive axle from the steering knuckle and hub. On some early model Ford Escorts and Lynx, a puller is required for this operation.

   Is the outer end of drive axle removed from steering knuckle and hub?
   ☐ Yes ☐ No

   Instructor check ____
5. Be sure the vehicle weight is supported on the hoist with the front suspension dropped downward. Remove the ball joint retaining nuts in the lower control arm.

   Are the lower ball joint retaining nuts removed? ☐ Yes ☐ No

   Instructor check ____

Task Completed

6. Remove the cotter pin from the tie-rod nut. Remove the outer tie-rod nut and use a puller to disconnect the tie-rod end from the steering knuckle.

   Is the outer tie-rod end removed? ☐ Yes ☐ No

   Instructor check ______________________________

7. If an eccentric cam is used on one of the strut-to-knuckle bolts, mark the cam and bolt position in relation to the strut and remove the strut-to-knuckle bolts.

   Is the eccentric camber marked in relation to the strut? ☐ Yes ☐ No

   Instructor check ______________________________

☐ 8. Remove the knuckle from the strut and lift the knuckle out of the chassis.

☐ 9. Pry the dust deflector from the steering knuckle with a large flat-blade screwdriver.

10. Use a puller to remove the ball joint from the steering knuckle. Check the ball joint and tie-rod end openings in the knuckle for wear and out-of-round. Replace the knuckle if these openings are worn or out-of-round.

    Condition of ball joint opening in the knuckle:

    ☐ Satisfactory ☐ Unsatisfactory

    Condition of tie-rod end opening in the knuckle:

    ☐ Satisfactory ☐ Unsatisfactory

    State the necessary steering knuckle and related repairs, and explain the reason for your diagnosis.

    ____

    ____

☐ 11. Use the proper driving tool to reinstall the dust deflector in the steering knuckle.

Instructor's Response ______________________________

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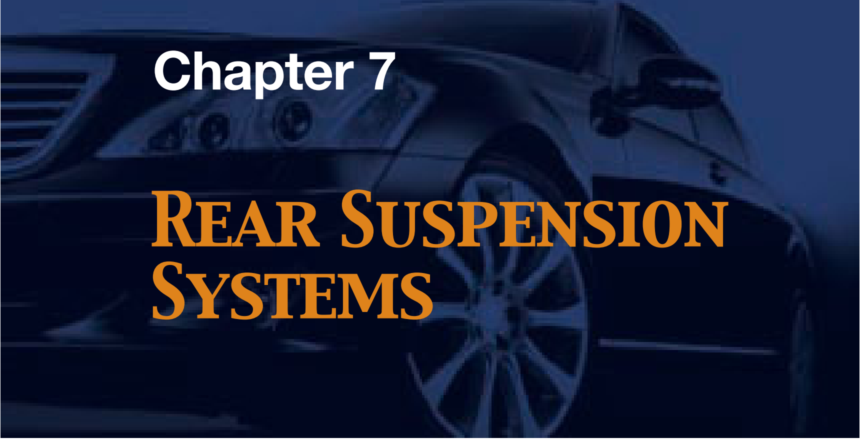


Chapter 7

REAR SUSPENSION SYSTEMS

UPON COMPLETION AND REVIEW OF THIS CHAPTER, YOU SHOULD BE ABLE TO UNDERSTAND AND DESCRIBE:

- A live-axle rear suspension system.
- The advantages and disadvantages of a live-axle leaf-spring rear suspension system.
- The movement of the rear axle housing during vehicle acceleration.
- How the differential torque is absorbed in a live-axle coil-spring rear suspension system.
- The purpose of a tracking bar in a live-axle coil-spring rear suspension system.
- The difference between a semi-independent and an independent rear suspension system.
- How individual rear wheel movement is provided in a semi-independent rear suspension system.
- The difference between a MacPherson strut and a modified MacPherson strut rear suspension.
- The advantage of attaching the differential housing to the chassis in an independent rear suspension system.
- How differential and suspension vibration, noise, and shock are insulated from the chassis in a multilink independent rear suspension system.
- How the top of the knuckle is supported in a multilink independent rear suspension system.
- The effect of sagged rear springs on caster angle and steering.

INTRODUCTION

A **rear suspension system** with two longitudinal leaf springs and a one-piece rear axle housing may be called a Hotchkiss drive.

A **live-axle rear suspension system** may be defined as one in which the differential axle housing, wheel bearings, and brakes act as a unit.

The **rear suspension system** plays a very important part in ride quality and in the control of suspension and differential noise, vibration, and shock. Although the front wheels actually steer the vehicle, the rear suspension is also vital to steering control. The rear suspension must also provide adequate tire life and maintain tire traction on the road surface. Rear suspension systems described in this chapter include live-axle, semi-independent, and independent. **Live-axle rear suspension systems** are found on rear-wheel-drive (RWD) trucks and vans, a few RWD cars, and some four-wheel-drive (4WD) cars. Most front-wheel-drive (FWD) vehicles have semi-independent or independent rear suspensions. Independent rear suspensions are also found on RWD cars and 4WD cars.

LIVE-AXLE REAR SUSPENSION SYSTEMS

Leaf-Spring Rear Suspension

A leaf spring is mounted longitudinally on each side of the rear suspension on some rear-wheel-drive cars and trucks (Figure 7-1). These relatively flat springs provide excellent lateral stability and reduce side sway, which contribute to a well-controlled ride with very good

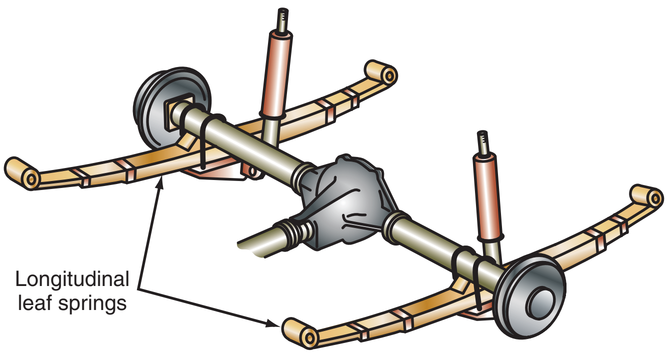


FIGURE 7-1 **Leaf-spring rear suspension system.**

handling characteristics. However, leaf-spring rear suspension systems have a lot of **unsprung weight**, and leaf springs require a considerable amount of space.

The **semielliptical springs** have steel leaves and zinc or plastic interleaves to reduce corrosion, friction, and noise. A large rubber bushing is installed in the front eye of the main spring leaf, and a bolt retains this bushing to the front spring hanger (Figure 7-2). The rear spring shackle is bolted to a rubber bushing in the rear main leaf eye, and the upper shackle bolt extends through a similar rubber bushing in the rear spring hanger (Figure 7-3). Some rear spring shackles contain threaded steel bushings or a slipper mount in which the end of the spring slides through the shackle. Shackle insulating bushings help prevent the transfer of noise and road shock from the suspension to the chassis and vehicle interior. When a rear wheel strikes a road irregularity, the spring is compressed and the spring length changes. The rear shackle provides fore-and-aft movement with variations in spring length.

Because the differential axle housing is a one-piece unit, jounce and rebound travel of one rear wheel affects the position of the other rear wheel. This action increases tire wear and decreases ride quality and traction.

The differential axle housing is mounted above the springs, and a spring plate with an insulating clamp and U-bolts retains the springs to the rear axle housing (Figure 7-4). The shock absorbers are mounted between the spring plates and the frame.

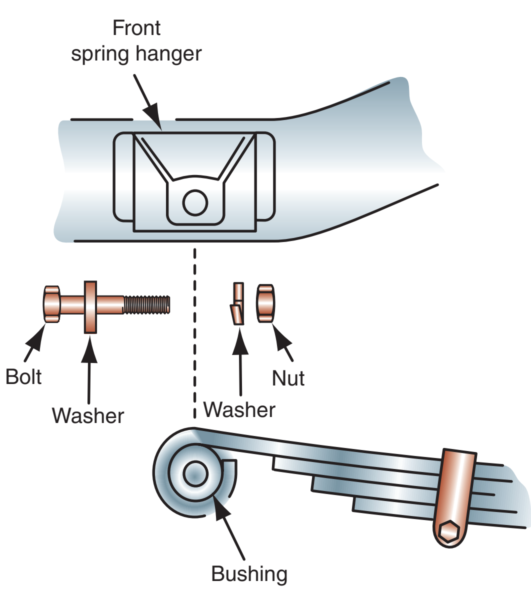


FIGURE 7-2 **Rear leaf-spring eye bushing.**

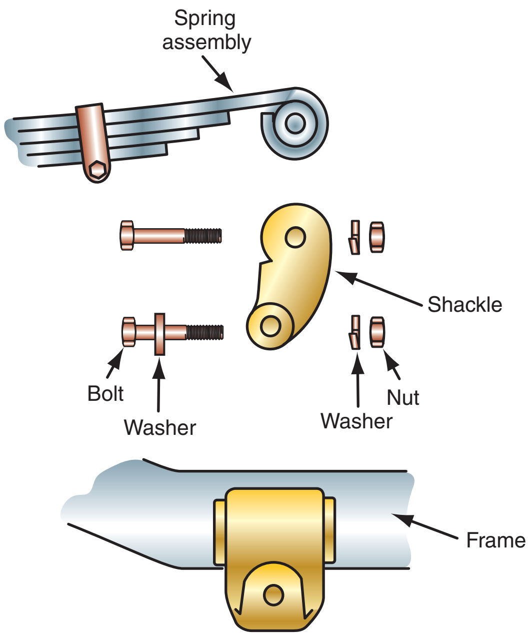
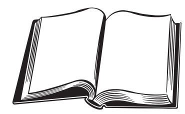


FIGURE 7-3 **Rear leaf-spring shackle.**



A Bit of History

The leaf-spring rear suspension was one of the first widely used rear suspension systems. Because this type of rear suspension system has weight and ride-quality disadvantages, it has been replaced on many vehicles with independent or semi-independent rear suspension systems.

Unsprung weight refers to the weight that is not supported by the springs, which includes the weight of the suspension system.

Semielliptical springs have individual leaves stacked with the shortest leaf at the bottom and the longest leaf at the top.

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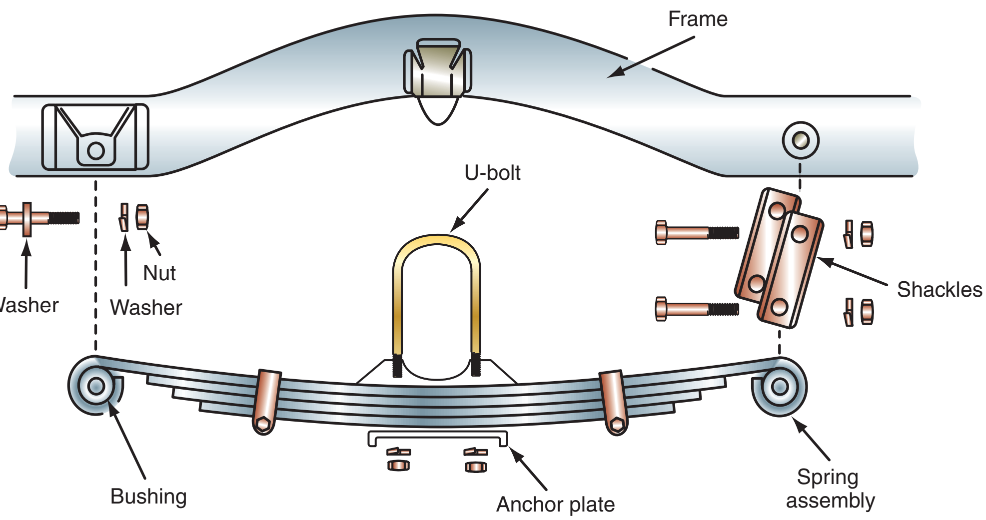

FIGURE 7-4 **Individual leaf-spring suspension components.**

Sprung weight refers to the weight carried by the springs, which includes the chassis and all components attached to the chassis.

The vehicle **sprung weight** is supported by the springs through the rear axle housing and wheels. When the vehicle accelerates, the rear wheels turn counterclockwise when viewed from the left vehicle side. One of Newton's laws of motion states that for every action there is an equal and opposite reaction. Therefore, when the wheels turn counterclockwise (when viewed from the left), the rear axle housing tries to rotate clockwise. This rear axle torque action is absorbed by the rear springs and the chassis moves downward (Figure 7-5). Engine torque supplied through the driveshaft to the differential tends to twist the differential housing and the springs. This twisting action may be referred to as **axle windup**. Many leaf springs have a shorter distance from the center bolt to the front of the spring compared to the distance from the center bolt to the rear of the spring. This type of leaf spring is referred to as an **asymmetrical leaf spring**, and the shorter distance from the center bolt to the front of the spring resists axle windup. A **symmetrical leaf spring** has the same distance from the center bolt to the front and rear of the spring.

When braking and decelerating, the rear axle housing tries to turn counterclockwise. This rear axle torque action applied to the springs lifts the chassis. This action may be called **braking and deceleration torque**.

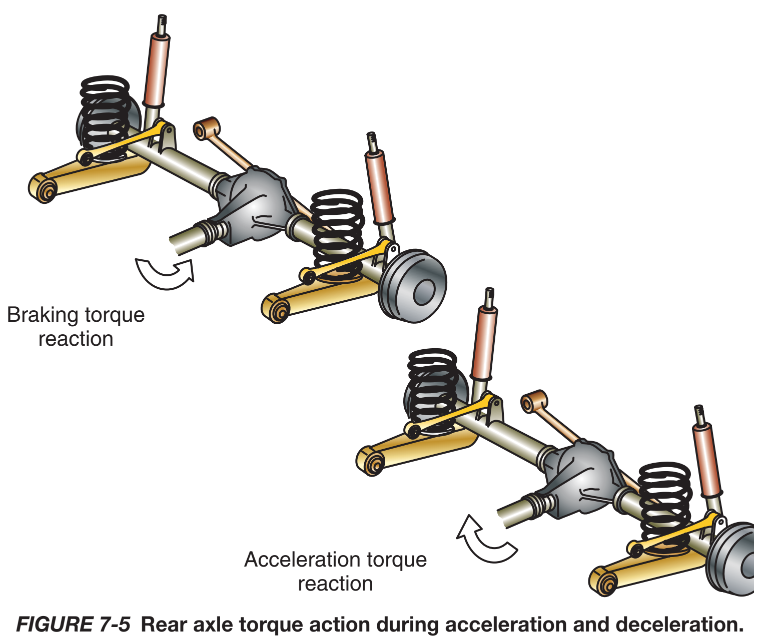

FIGURE 7-5 **Rear axle torque action during acceleration and deceleration.**

During hard acceleration, the entire power train twists in the opposite direction to engine crankshaft and drive shaft rotation. The engine and transmission mounts absorb this torque. However, the twisting action of the drive shaft and differential pinion shaft tends to lift the rear wheel on the passenger's side of the vehicle. Extremely hard acceleration may cause the rear wheel on the passenger's side to lift off the road surface. Once this rear wheel slips on the road surface, engine torque is reduced, and the leaf spring forces the wheel downward. When this rear tire contacts the road surface, engine torque increases and the cycle repeats. This repeated lifting of the differential housing is called **axle tramp**, and this action occurs on live-axle rear suspension systems. Axle tramp is more noticeable on live-axle leaf-spring rear suspension systems in which the springs have to absorb all the differential torque. For this reason, only engines with moderate horsepower were used with this type of rear suspension. Rear suspension and axle components such as spring mounts, shock absorbers, and wheel bearings may be damaged by axle tramp. Mounting one rear shock absorber in front of the rear axle and the other rear shock behind the rear axle helps reduce axle tramp.

AUTHOR'S NOTE: Leaf-spring rear suspension systems are still used on many light-duty trucks because of their load-carrying capability. However, today's design engineers have improved the ride quality of these suspension systems compared with past models. Ride quality in these leaf-spring suspension systems has been improved by installing longer leaf springs and using larger, improved rubber insulating bushings in the spring eye and shackle. Ride quality has also been improved by maximizing the shock absorber mounting location and matching the shock absorber design more closely to the leaf-spring jounce and rebound action. Optimizing the rear axle mounting position on the leaf springs also improves ride quality.

In some cars with higher torque engines, a long torque arm is bolted to the rear axle housing (Figure 7-6). This torque arm helps prevent differential rotation during hard acceleration and braking. The front of this torque arm is mounted in a rubber insulator and bracket that is bolted to the back of the transmission housing. This long torque arm helps prevent

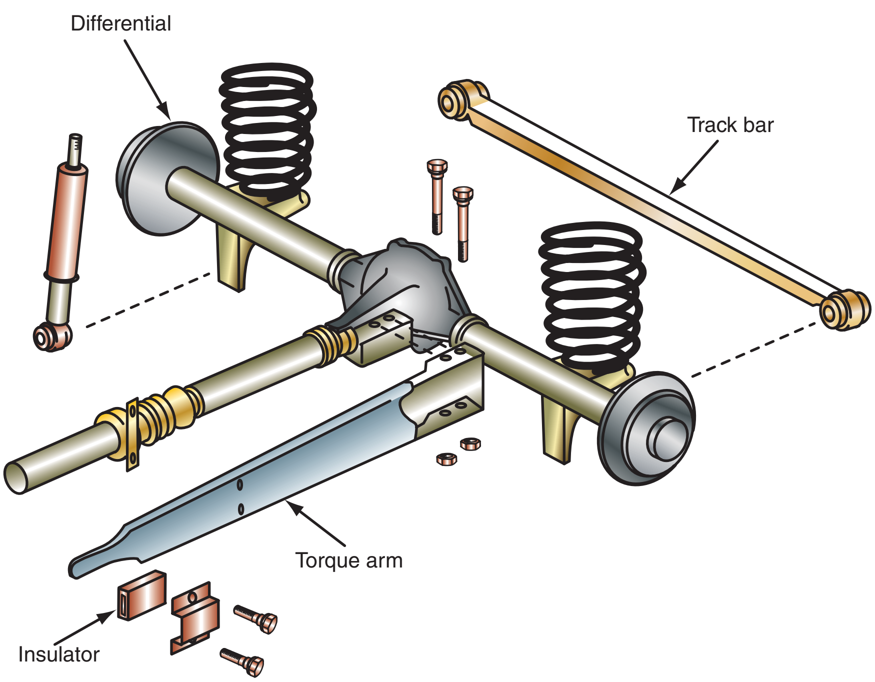

FIGURE 7-6 **Rear suspension system with long torque arm and track bar.**

differential rotation when high torque is delivered from the engine to the differential. The center bearing assembly on the drive shaft is bolted to the long torque arm. This rear suspension system has a track bar (tie-rod) connected from the left side of the rear axle housing to the chassis to help prevent lateral rear axle movement. A track bar brace is connected from the chassis end of the track bar to the other side of the chassis to provide extra rigidity.

Coil-Spring Rear Suspension

WARNING: Compressed coil springs contain a large amount of energy. Never disconnect any suspension component that suddenly releases the coil-spring tension. This action may result in personal injury and vehicle damage.

WARNING: Always follow the vehicle manufacturer's recommended rear suspension service procedures in the service manual to avoid personal injury.

Some rear-wheel-drive cars have a coil-spring rear suspension. Upper and lower suspension arms with insulating bushings are connected between the differential housing and the frame (Figure 7-7). The upper arms control lateral movement, and the lower trailing control arms absorb differential torque. In some rear suspension systems, the upper arms are replaced with strut rods. The front of the upper and lower arms contains large rubber bushings. When strut rods are used in place of the upper arms, both ends of these rods contain large rubber bushings to prevent noise and vibration transfer from the suspension to the chassis. The coil springs are usually mounted between the lower suspension arms and the frame, whereas the shock absorbers are mounted between the back of the suspension arms and the frame.

A **track bar** may be referred to as a Panhard rod or Watts rod.

Some rear suspension systems have a **track bar** connected from one side of the differential housing to the chassis to prevent lateral chassis movement. Large rubber insulating bushings are positioned in each end of the track bar.

Some late model sport utility vehicles (SUVs) have a rear suspension system with coil springs and shock absorbers mounted separately from the springs (Figure 7-8). Notice that a control rod is mounted in rubber insulating bushings on the bottom of the rear axle housing, and the outer end of this bar is connected through links to the chassis. This rear suspension has an upper and lower control rod on each side of the suspension. Each lower control rod

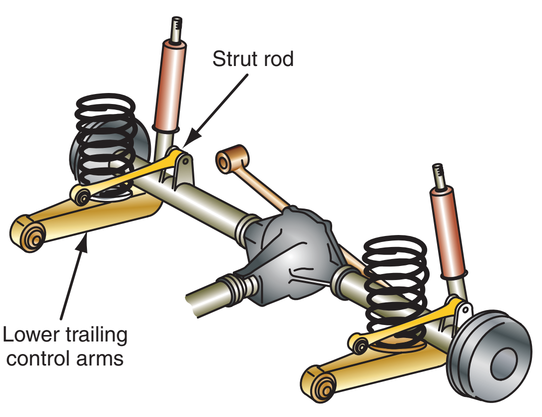

FIGURE 7-7 **Live-axle coil-spring rear suspension.**

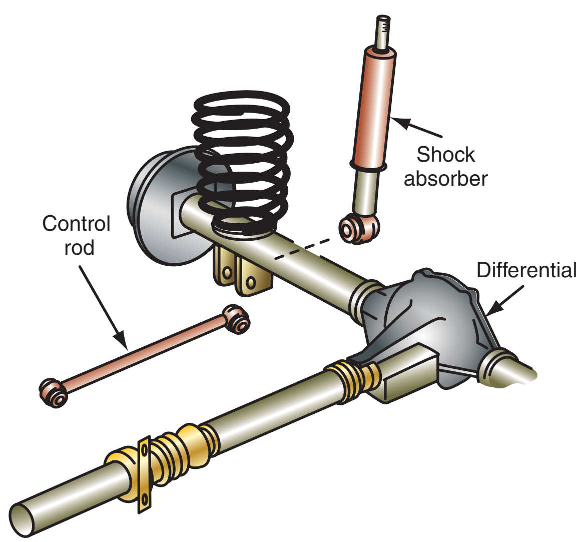

FIGURE 7-8 **Rear suspension system with coil springs and shock absorbers mounted separately.**

is connected from a bracket on the lower side of the axle housing to a frame bracket. Rubber insulating bushings are located in both ends of the lower control rods. The frame bracket is located ahead of the rear axle. The upper control rod is connected from a bracket on top of the axle housing to a frame bracket near the lower control rod frame bracket (Figure 7-9). Both ends of the upper control rod contain rubber insulating bushings. The upper and lower control rods prevent rear axle windup during hard acceleration.

This SUV rear suspension also has a track bar connected from a bracket on the rear of the axle housing to a frame bracket on the opposite side of the vehicle. The track bar prevents lateral rear axle movement. A rear axle brace is also connected from the track bar frame bracket to another frame bracket on the opposite side of the vehicle (Figure 7-10). The rear axle brace prevents any movement of the track bar frame bracket during off-road or severe driving conditions. The dual rear axle rods on each side of this suspension with the track bar and brace provide a very stable rear axle position during hard acceleration and severe driving conditions. This rear axle stability improves tire life, ride comfort, and steering control.

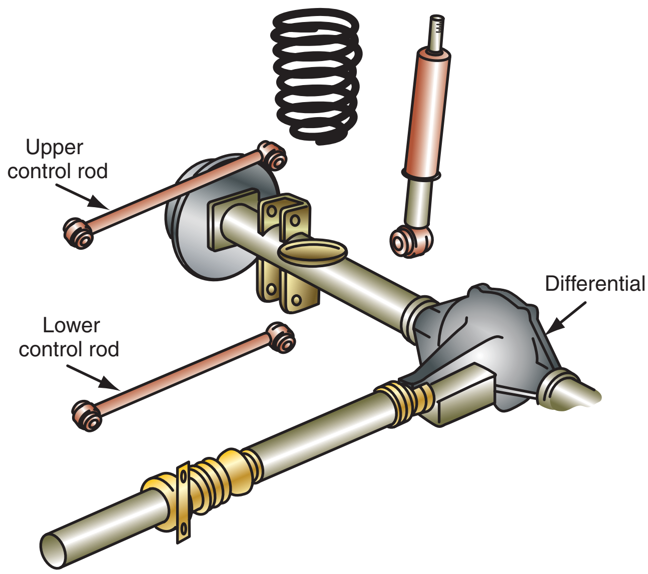

FIGURE 7-9 **Rear suspension system with upper and lower control rods.**

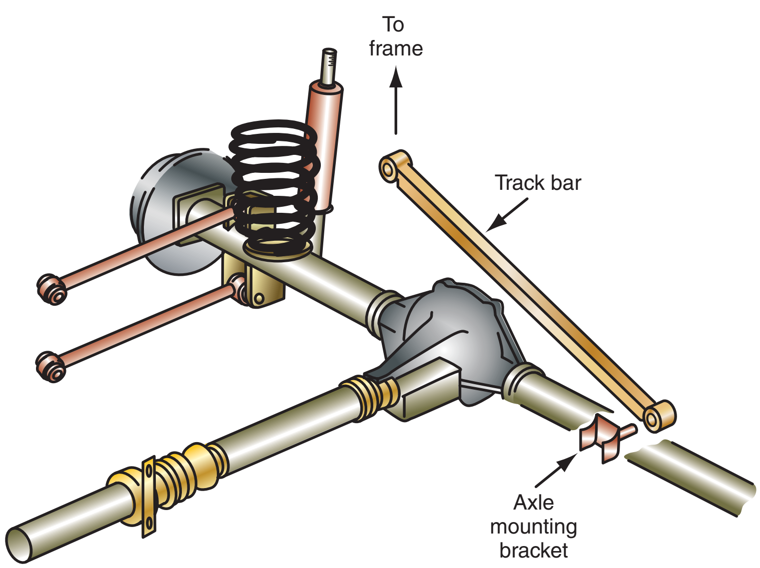

FIGURE 7-10 **Track bar and brace.**

Semi-Independent Rear Suspension Systems

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A **semi-independent rear suspension** allows some individual rear wheel movement when one rear wheel strikes a bump.

Many front-wheel-drive vehicles have a **semi-independent rear suspension** that has a **solid axle beam** connected between the rear trailing arms (Figure 7-11). A solid axle beam is usually a transverse inverted U-section channel connected between the rear wheels in a semi-independent rear suspension system. When one rear wheel strikes a bump, this beam twists to allow some independent wheel movement. Some of these rear axle beams are fabricated from a transverse inverted U-section channel.

In some rear suspension systems, the inverted U-section channel contains an integral tubular stabilizer bar. When one rear wheel strikes a road irregularity and the wheel moves upward, the inverted U-section channel twists, which allows some independent rear wheel movement. The trailing arms are connected to chassis brackets through rubber insulating bushings. In some semi-independent rear suspension systems, the coil springs are mounted on the rear struts, the lower spring seat is located on the strut, and the upper spring seat is positioned on the upper strut mount.

In other semi-independent rear suspension systems, the coil springs are mounted separately from the shock absorbers. Coil-spring seats are located on the trailing arms, and the shock absorbers are connected from the trailing arms to the chassis. A crossmember connected between the trailing arms provides a twisting action and some independent rear wheel movement (Figure 7-12).

Some semi-independent rear suspension systems have a track bar connected from a rear axle bracket to a chassis bracket. In some applications, an extra brace is connected from this chassis bracket to the rear upper crossmember (Figure 7-13). The track bar and the brace prevent lateral rear axle movement.

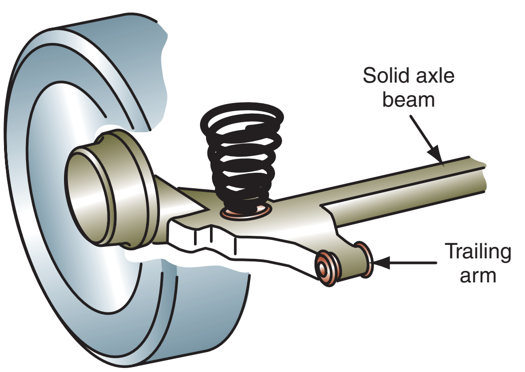

FIGURE 7-11 **Semi-independent rear suspension system.**

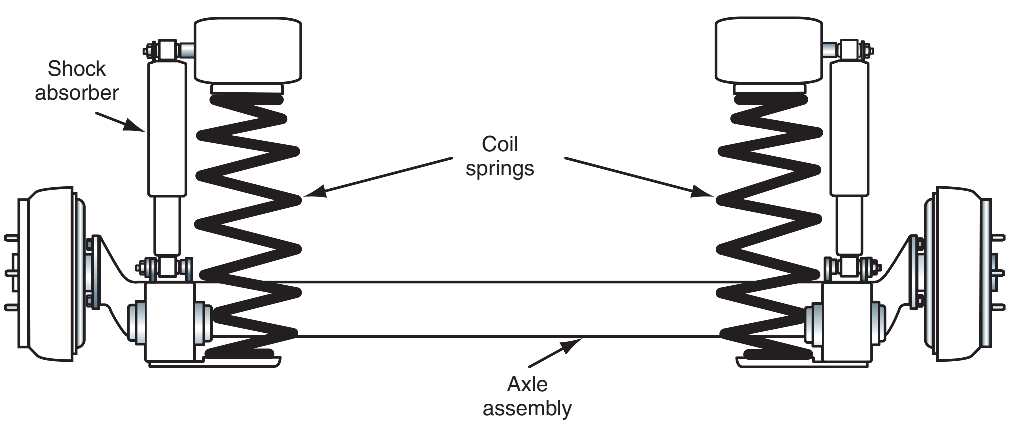

FIGURE 7-12 **Semi-independent rear suspension system with coil springs and shock absorbers mounted separately.**

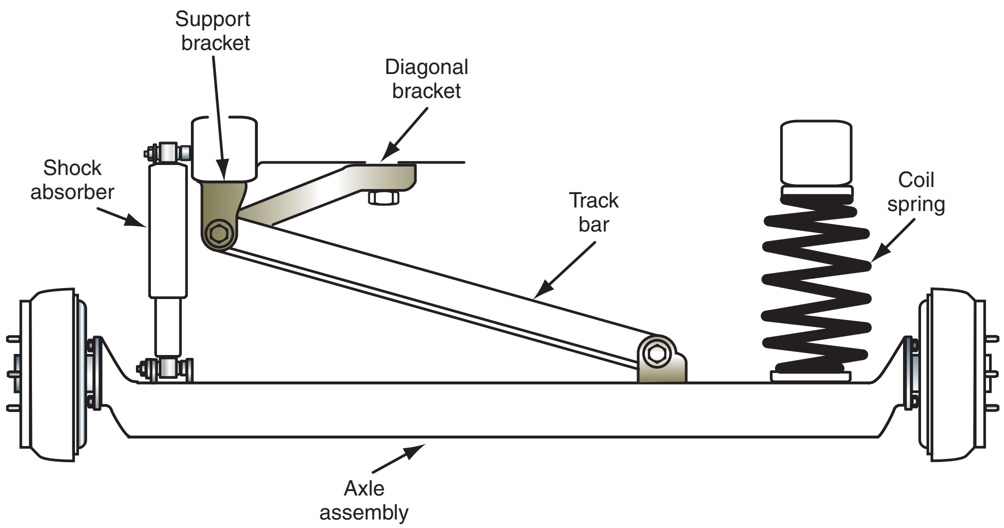

FIGURE 7-13 **Semi-independent rear suspension with track bar and brace.**

Independent Rear Suspension Systems

MacPherson Strut Independent Rear Suspension System

In an **independent rear suspension** system, each rear wheel can move independently from the opposite rear wheel. Independent rear suspension systems may be found on front-wheel-drive and rear-wheel-drive vehicles. When rear wheel movement is independent, ride quality, tire life, steering control, and traction are improved. In a MacPherson strut rear suspension system, the coil springs are mounted on the rear struts. A lower spring seat is located on the strut, and the upper spring seat is positioned on the upper strut mount. This upper strut mount is bolted into the inner fender reinforcement. Dual lower control arms on each side of the suspension are connected from the chassis to the lower end of the spindle (Figure 7-14).

In an **independent rear suspension**, vertical movement of one rear wheel does not affect the opposite rear wheel.

The lower end of each strut is bolted to the spindle. Two strut rods are connected forward from the spindles to the chassis. Rubber insulating bushings are located in both ends of the strut rods. A stabilizer bar is mounted in rubber bushings connected to the chassis, and the ends of this bar are linked to the struts.

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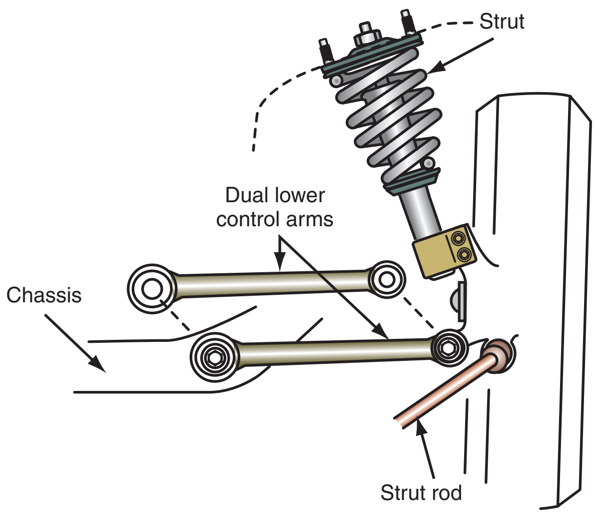

FIGURE 7-14 **MacPherson strut independent rear suspension system.**

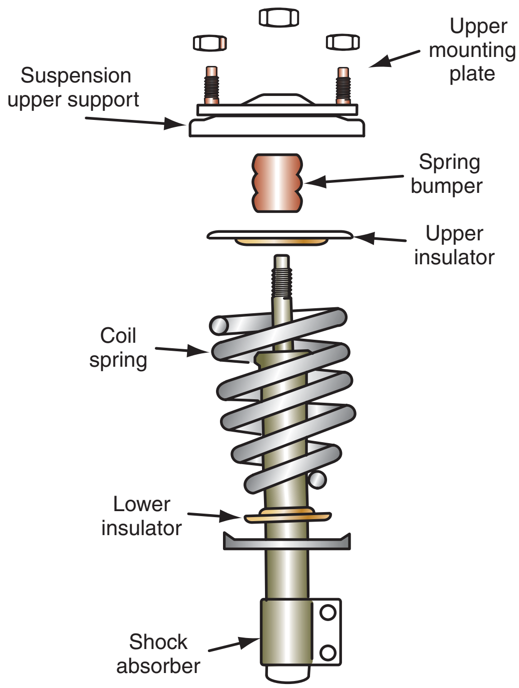

FIGURE 7-15 **Upper and lower spring insulators, MacPherson strut independent rear suspension.**

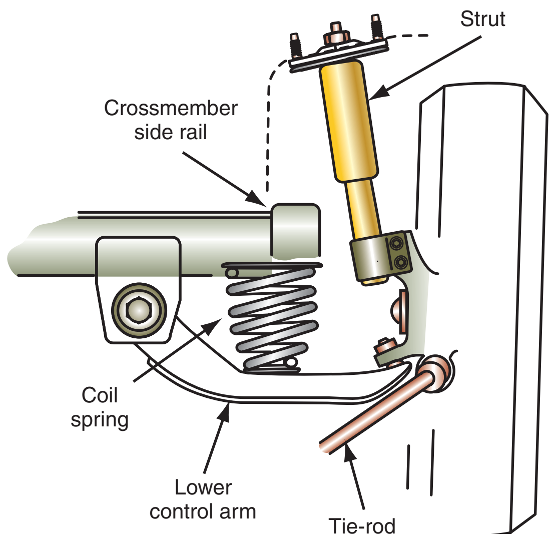

FIGURE 7-16 **Modified MacPherson strut independent rear suspension.**

Insulators are mounted between the lower end of the coil spring and the lower spring seat, and the top of the coil spring and the upper spring support (Figure 7-15). These insulators help prevent the transfer of spring noise and vibration to the chassis and passenger compartment.

Modified MacPherson Strut Independent Rear Suspension System

Some front-wheel-drive vehicles have a modified MacPherson strut independent rear suspension. Each side of the rear suspension has a shock strut, lower control arm, tie-rod, forged spindle, and coil spring mounted between the lower control arm and crossmember side rail (Figure 7-16).

The shock absorber strut has a rubber isolated top mount with a one-piece jounce bouncer dust shield. This top mount is attached to the body side panel and the lower end of the strut is bolted to the spindle. The stamped lower control arms are bolted to the crossmember and the spindle. A tie-rod is connected from the spindle to the underbody. The purpose of each rear suspension component may be summarized as follows:

1. Stamped lower control arm—controls the lateral (side-to-side) wheel movement and contains the lower spring seat.
2. Tie-rod—controls fore-and-aft wheel movement and positions the spindle properly.
3. Shock absorber strut—reacts to braking forces and provides suspension damping. A strut internal rebound stop provides rebound control, and an external jounce bumper supplies jounce control.
4. Coil spring—controls suspension travel, provides ride height control, and acts as a metal-to-metal jounce stop.
5. Forged spindle—supports the wheel bearings and attaches to the lower control arms, tie-rod, brake assembly, and strut.
6. Suspension bushings—insulate the chassis and passenger compartment from road noise and vibration.
7. Suspension fasteners—connect components such as the spindle and strut. These fasteners must always be replaced with equivalent quality parts, and each fastener must be tightened to the specified torque.

Independent Rear Suspension with Lower Control Arm and Ball Joint

Some front-wheel-drive cars have an independent rear suspension system with a ball joint pressed into the outer end of the lower control arm. The ball joint contains a conventional wear indicator. The upper end of the ball joint stud is bolted into the knuckle (Figure 7-17). The inner end of the lower control arm is connected to the chassis through two rubber insulating bushings (Figure 7-18).

The lower end of the strut is bolted to the knuckle, and the upper strut mount is bolted to the inner fender reinforcement (Figure 7-19). A stabilizer bar is mounted in bushings attached to the chassis, and the outer ends of this bar are linked to brackets connected to the strut (Figure 7-20).

A suspension adjustment link is connected from the lower control arm to the knuckle (Figure 7-21). This link provides a **rear wheel toe** adjustment. A coil-spring seat is located in the lower control arm and the coil spring is mounted between this seat and an upper seat in the chassis (Figure 7-22). Upper and lower insulators are mounted between the coil spring and the seats.

Rear wheel toe is the variation between the distance measured between the tires at the front edge and the rear edge. If the distance between the front edge of the tires is less than the distance between the rear edge of the tires, the rear wheels have toe-in.

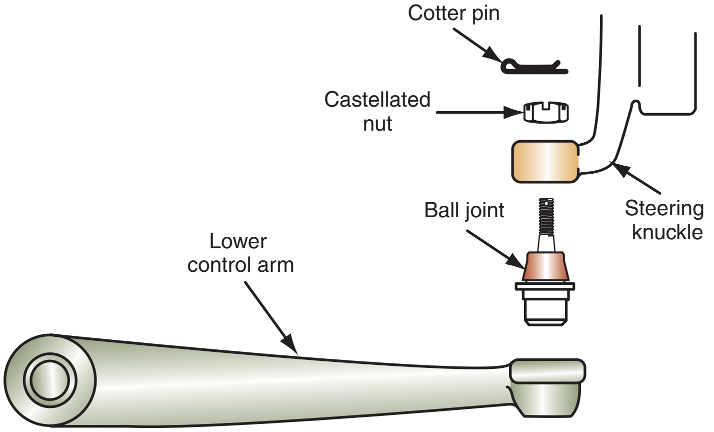

FIGURE 7-17 **Lower control arm and ball joint.**

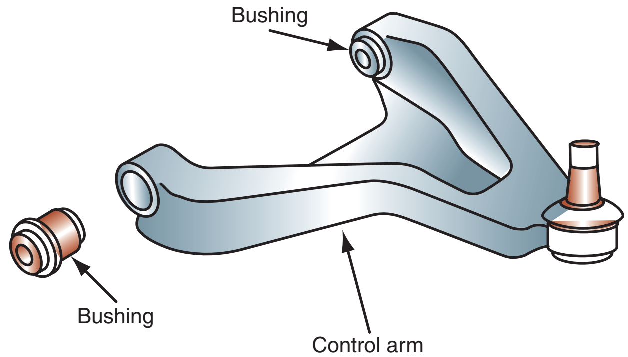

FIGURE 7-18 **Lower control arm bushings.**

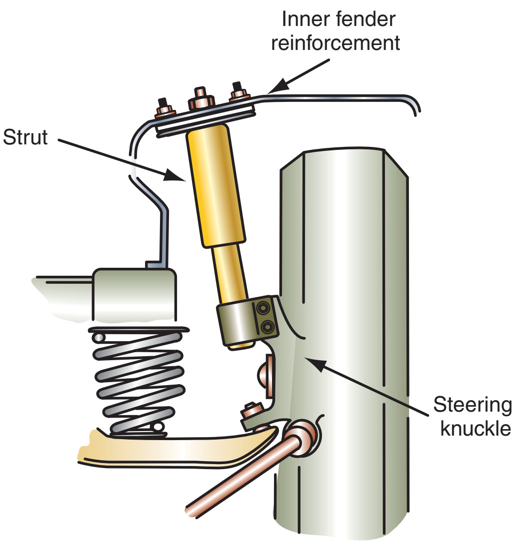

FIGURE 7-19 **Upper and lower strut mounting.**

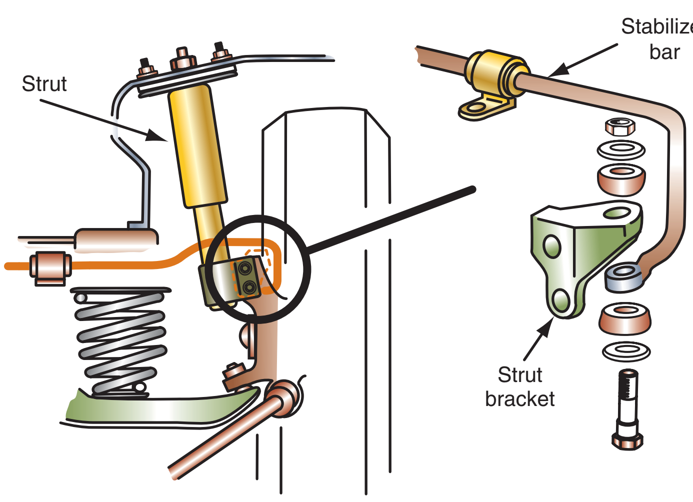

FIGURE 7-20 **Stabilizer bar mounting.**

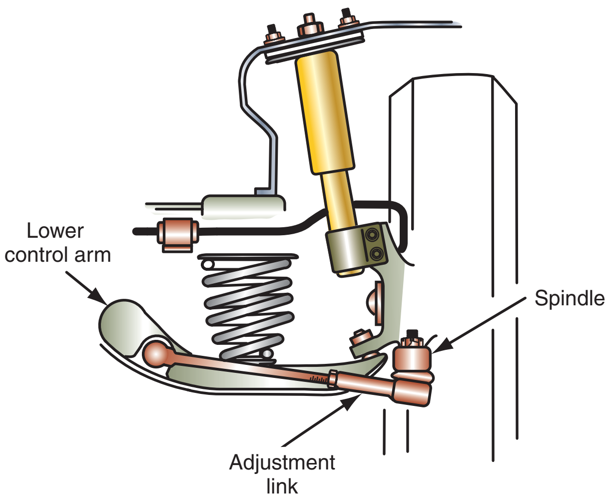

FIGURE 7-21 **Suspension adjustment link.**

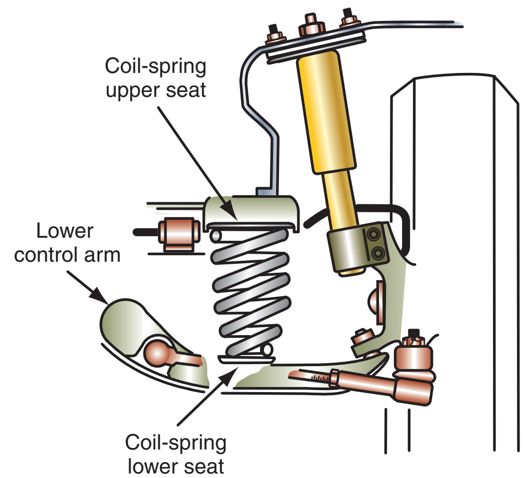

FIGURE 7-22 **Coil-spring mounting.**

Independent Short-and-Long Arm Rear Suspension System

Some late model SUVs have a short-and-long arm (SLA) independent rear suspension system (Figure 7-23). This type of suspension system has upper and lower control arms, and the coil springs are mounted on the shock absorbers. The lower end of the shock absorber is mounted to the lower control arm with a rubber bushing. An upper rubber-insulated mount is positioned between the top of the shock absorber and the chassis. A toe link is connected from the spindle to the chassis, and the inner end of this link may be rotated to adjust the rear wheel toe. The inner end of the upper control arm is secured to the chassis with rubber insulating bushings (Figure 7-24). The SLA independent rear suspension system design allows the rear floor in the SUV to be lowered 5 in. This body design allows extra cargo space and more headroom in the rear of the vehicle if the optional third seat is installed.

Independent Rear Suspension System with Rear Axle Carrier

Some import rear-wheel-drive cars have an independent rear suspension with a large rear axle carrier extending across the width of the chassis. A large extension on the rear axle

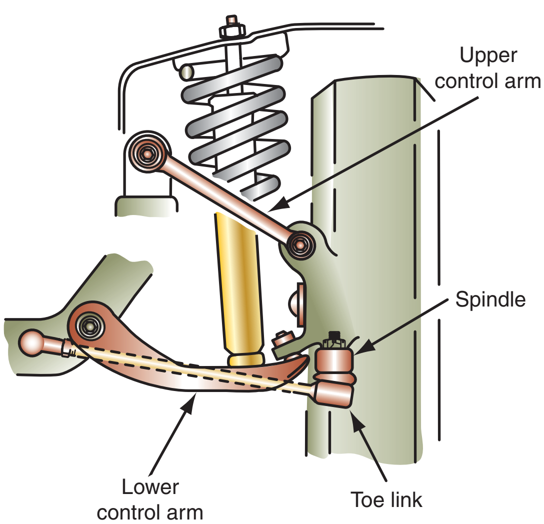

FIGURE 7-23 **Short-and-long arm independent rear suspension system.**

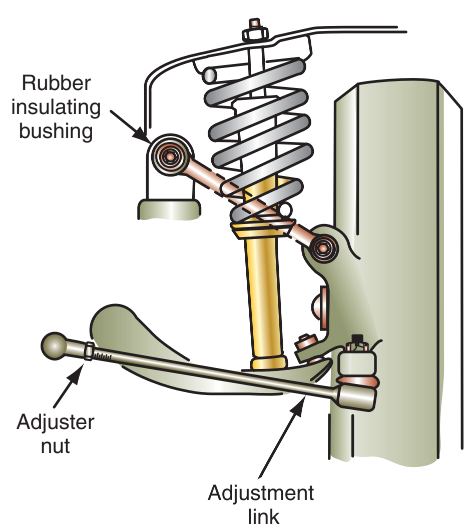

FIGURE 7-24 **Upper control arm, short-and-long arm independent rear suspension system.**

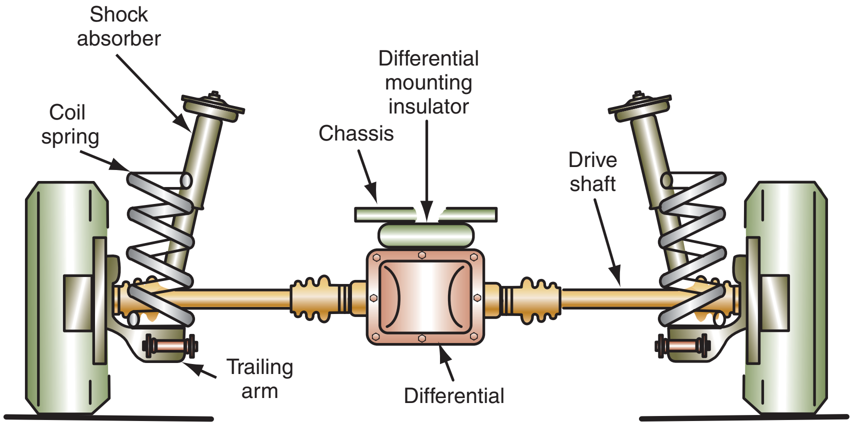

FIGURE 7-25 **Independent rear suspension with rear axle carrier.**

carrier is bolted to the top of the differential, and the outer ends of this carrier are connected through heavy insulating bushings to chassis brackets (Figure 7-25).

A large final drive mount extends from the rear of the differential housing, and this mount is bolted to the chassis. When the differential is attached to the chassis, rather than being connected to the suspension, the unsprung weight is reduced. Two rubber insulating bushings connect the large trailing arms to the rear axle carrier. The rear axle carrier provides very stable differential and wheel position, which improves steering control, ride quality, and tire life. Lower coil-spring seats are located on the trailing arms, and upper coil-spring seats are positioned in the chassis.

Shock absorbers are connected from the back of the trailing arms to the chassis. The rear wheel bearings are mounted in the outer ends of the trailing arms. Drive axles with inner and outer drive joints are connected from the differential to the rear wheels. When the drive axles have inner and outer joints, rear wheel camber change is minimized during wheel jounce and rebound. On some early independent rear suspension systems in rear-wheel-drive cars, the drive axles had only inner joints. With this type of rear suspension and drive axle, camber change was excessive during wheel jounce and rebound, and this action caused wear on the tire edges.

A stabilizer bar is bolted to the rear axle carrier through rubber insulating bushings. The outer ends of this bar are linked to the trailing arms.

Multilink Independent Rear Suspension System

Many vehicles have a **multilink independent rear suspension system**. A typical multilink rear suspension system has upper and lower control arms and additional links connected from the rear knuckles to the chassis to stabilize the rear wheel position. The suspension components are attached to the rear frame. The lower control arm is connected from the rear frame to the lower end of the knuckle. A large bushing is mounted in the inner end of the control arm at the frame attachment location (Figure 7-26). The coil springs are mounted between the lower control arms and the rear chassis, and insulators are positioned on the upper and lower ends of the springs. The upper control arms are connected from the rear frame to the top of the knuckle. The inner end of each upper control arm has two attachment points to frame, and large insulating bushings are installed at these attachment locations (Figure 7-27). A ball joint in the outer end of each upper control arm connects the control arm to the top end of the knuckle. Many current rear suspension systems have aluminum components such as upper and lower control arms. Aluminum components reduce weight and improve fuel mileage, which in turn reduces emissions.

A trailing arm in connected from the lower end of the knuckle to the frame. Large insulating bushings are mounted at each trailing arm attachment location (Figure 7-28). The

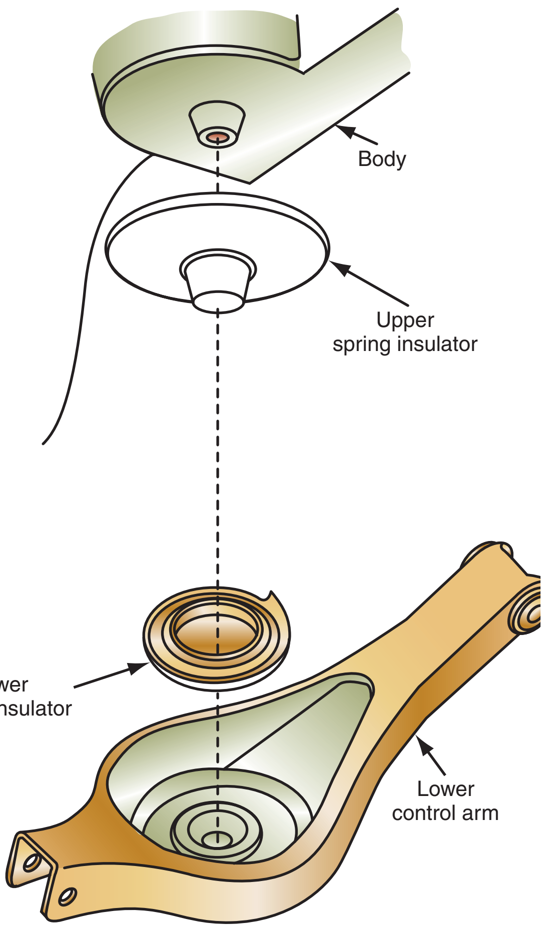

FIGURE 7-26 **Lower control arm with upper and lower spring insulators.**

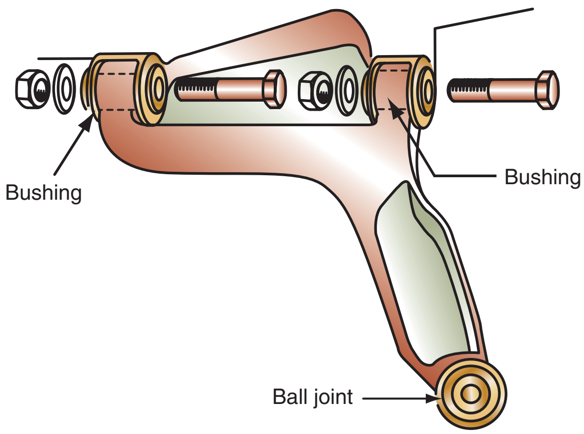

FIGURE 7-27 **The upper control arm is connected from the frame to the top of the knuckle.**

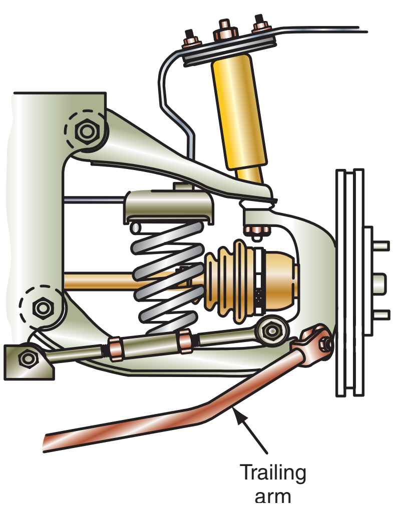

FIGURE 7-28 **The trailing arm is connected from the lower end of the knuckle to the frame.**

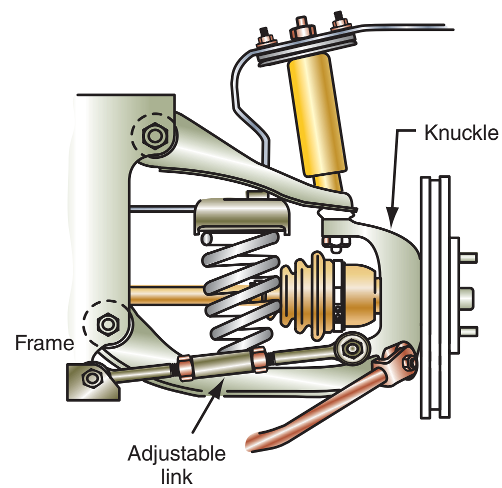

FIGURE 7-29 **Adjustment link.**

A **five-link suspension** has five attachment locations between each side of the suspension and the frame.

trailing arm prevents fore-and-aft wheel movement. An adjustment link is also connected from the lower end of the knuckle to the frame through insulating bushings (Figure 7-29). The adjustment link and lower control arm prevent lateral wheel movement, and this link also provides a method of rear wheel toe adjustment. This type of rear suspension may be called a **five-link suspension** because there are five attachments points between each

knuckle and the frame. The lower control arm, trailing arm, and adjustment link each have one attachment location, and the upper control arm has two attachment points. A five-link rear suspension provides a very stable rear wheel position, which improves steering control and rear tire tread life.

The shock absorbers are connected from the rear knuckles to the chassis (Figure 7-30). Two bolts retain the upper insulating shock absorber mount to the chassis. In this rear-wheel-drive car, the top of the differential is bolted to the upper part of the rear frame. Two large insulating bushings are mounted between the differential and the frame (Figure 7-31). Mounting the differential to the frame reduces the unsprung weight, which improves ride quality, because the unsprung weight forces the wheels downward during wheel rebound, which contributes to harsh ride quality.

In some current multilink rear suspension systems on rear wheel drive vehicles, four large rubber mounts are positioned between the rear suspension member or frame and the chassis. These rubber mounts are designed such that they are soft in fore/aft movement but stiff in lateral movement. These rubber mounts reduce the transfer of road vibrations and shocks from the rear suspension system to the body. The stiff lateral movement in these bushings maintains lateral rear wheel position to reduce rear tire wear and improve vehicle stability.

Some multilink rear suspension systems have four hydraulic mounts mounted between the rear suspension member or frame and the chassis. The differential is bolted to the rear frame. These hydraulic mounts contain a silicone oil that helps prevent noise, vibration, and shock transfer from the differential and suspension to the chassis and vehicle interior (Figure 7-32).

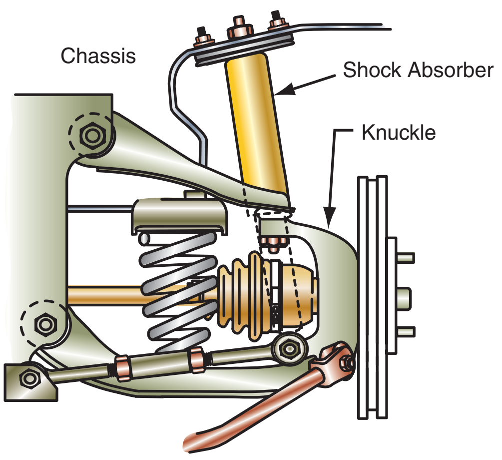

FIGURE 7-30 **Shock absorber mounting.**

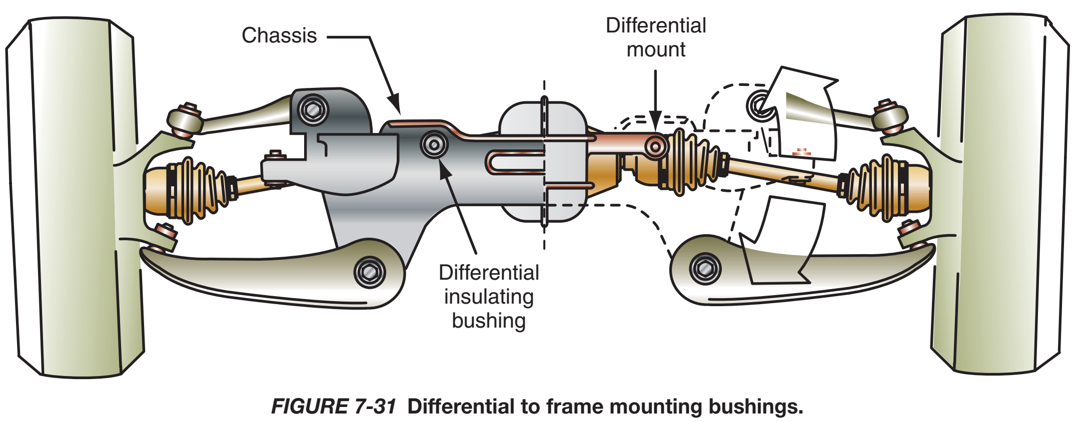

FIGURE 7-31 **Differential to frame mounting bushings.**

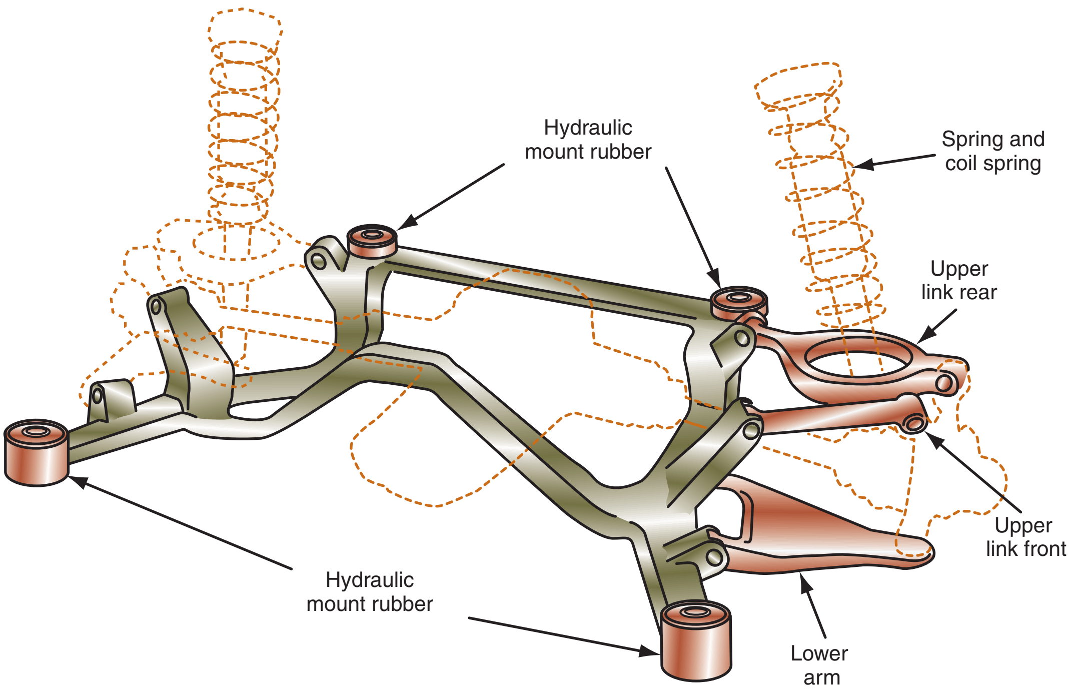

FIGURE 7-32 **Multilink independent rear suspension system with hydraulic mounts.**

The rear suspension member is connected to the outer shell of the hydraulic mounts, and the inner shell is attached to the chassis. Silicone oil fills the area between the inner and outer shells in each mount (Figure 7-33). Noise, vibration, and shock are transferred from the differential and suspension to the rear suspension member, but the silicone oil in the hydraulic mounts prevents the transfer of these undesirable forces to the chassis and vehicle interior. These hydraulic mounts have superior noise and vibration dampening characteristics compared to rubber bushings.

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A rear upper link is connected from each side of the rear suspension member to the top of the knuckles. Both ends of this rear upper link contain rubber insulating bushings. The lower end of the shock absorber strut extends through a circular opening in the rear upper link. A front upper link is also connected from the rear suspension member to the knuckle. The top of the knuckle is supported by the front and rear upper links, rather than being supported by the shock absorber strut. The coil springs are mounted on the shock absorber struts, and the lower spring seat is attached to the strut. An upper spring seat is attached to the top of the shock

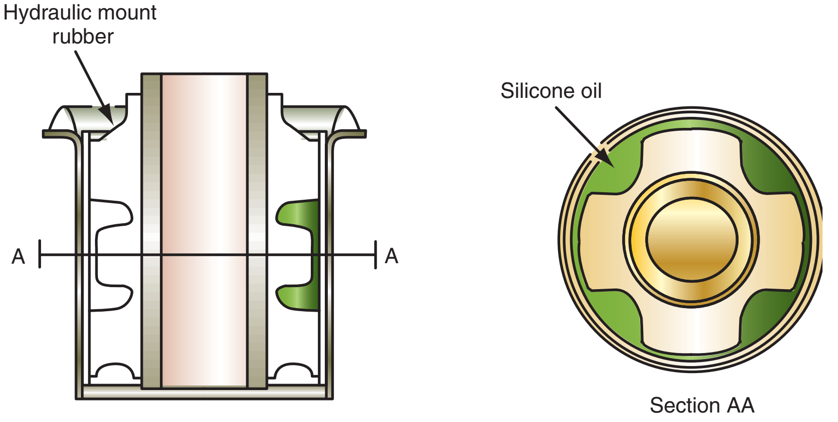

FIGURE 7-33 **Hydraulic mount design.**

absorber strut, and this upper seat is bolted into the inner fender reinforcement. The lower end of the shock absorber strut is connected to the back of the lower control arm. Lower control arms are connected from the rear suspension member to the lower end of the knuckles.

Some multilink rear suspension systems have a lower control arm and a toe control arm parallel to the lower control arm (Figure 7-34). A bolt in the outer end of the lower control arm extends through a bushing in the lower end of the steering knuckle. A ball joint in the outer end of the toe control arm is bolted into the lower end of the knuckle. Rubber insulating bushings are pressed into the inner ends of the toe control arm and lower control arm. Bolts extend through these bushings and openings in the chassis. The rear end of the trailing arm is bolted to a bushing in the knuckle, and a bushing in the front end of this arm is bolted to the chassis. The trailing arm, lower control arm, and toe control arm prevent lateral and fore-and-aft wheel movement and provide excellent suspension rigidity when cornering or driving on irregular road surfaces. An eccentric cam bolt on the inner end of the toe control arm provides a rear wheel toe adjustment (Figure 7-35).

A bushing in the upper end of the knuckle is bolted to the outer end of the upper control arm (Figure 7-36). Front and rear bushings in the inner ends of the upper control arm are bolted to brackets that are in turn bolted to the chassis.

The one-piece rear wheel bearing assemblies are bolted to the knuckles (Figure 7-37). If the vehicle has an antilock brake system, the toothed ring is attached to the inner end of each rear wheel bearing and stub axle shaft, and a wheel-speed sensor is mounted in the knuckle. The rear wheel bearings assemblies are non-serviceable.

Double Wishbone Rear Suspension

In the **double wishbone rear suspension system**, the upper and lower control arms are manufactured from lightweight, high-strength aluminum alloys designed for maximum strength and rigidity. These lighter control arms decrease the unsprung weight, which helps improve traction and ride quality. Suspension rigidity is also increased by positioning the ball joints and steering knuckle inside the wheel profile (Figure 7-38). Since the upper and lower control arms have a wishbone shape, the term "double wishbone" suspension system is used for this type of rear suspension. On each side of the car, the rear suspension is attached to the chassis

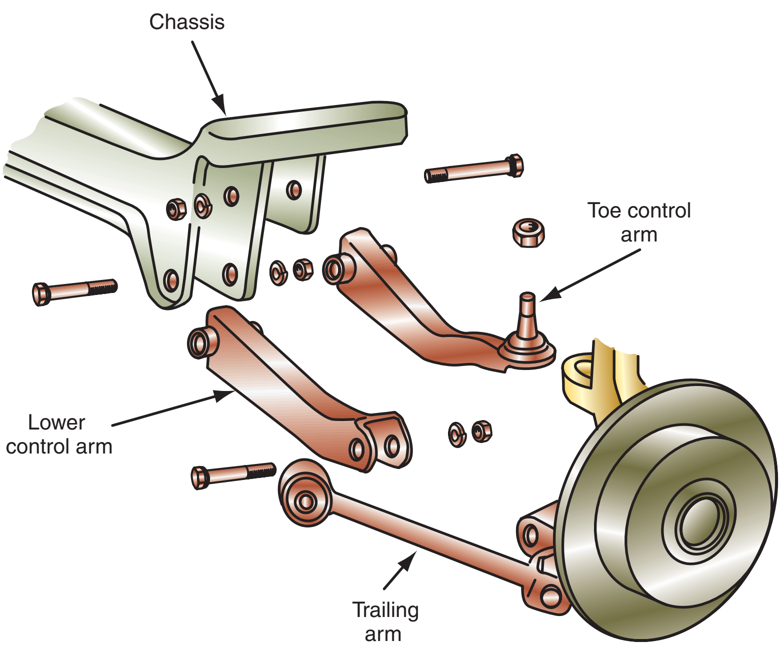

FIGURE 7-34 **Multilink rear suspension with parallel lower control arm and toe control arm.**

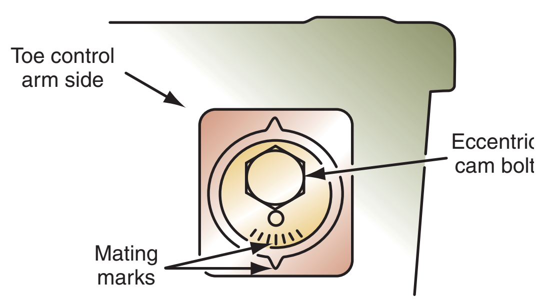

FIGURE 7-35 **Eccentric cam bolt on inner end of toe control arm.**

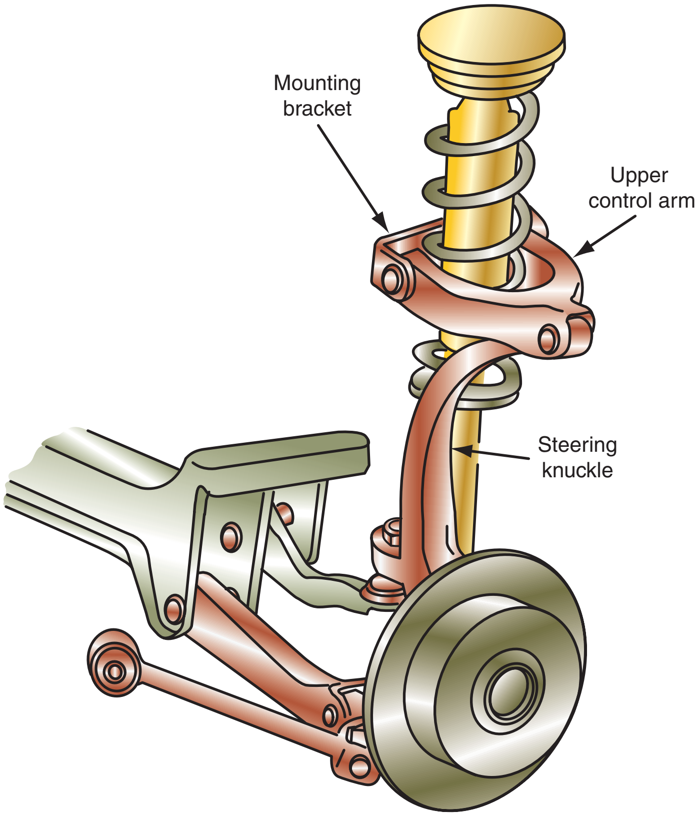

FIGURE 7-36 Upper control arm and strut in multilink rear suspension.

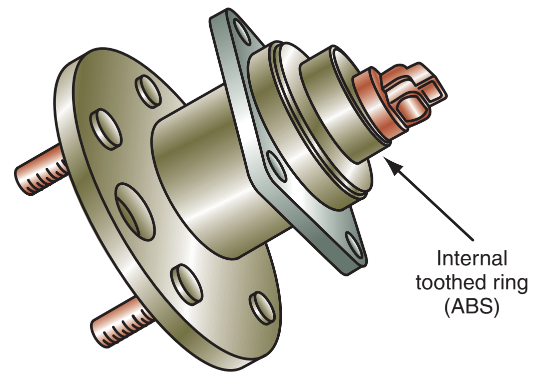

FIGURE 7-37 One-piece rear wheel bearing assembly.

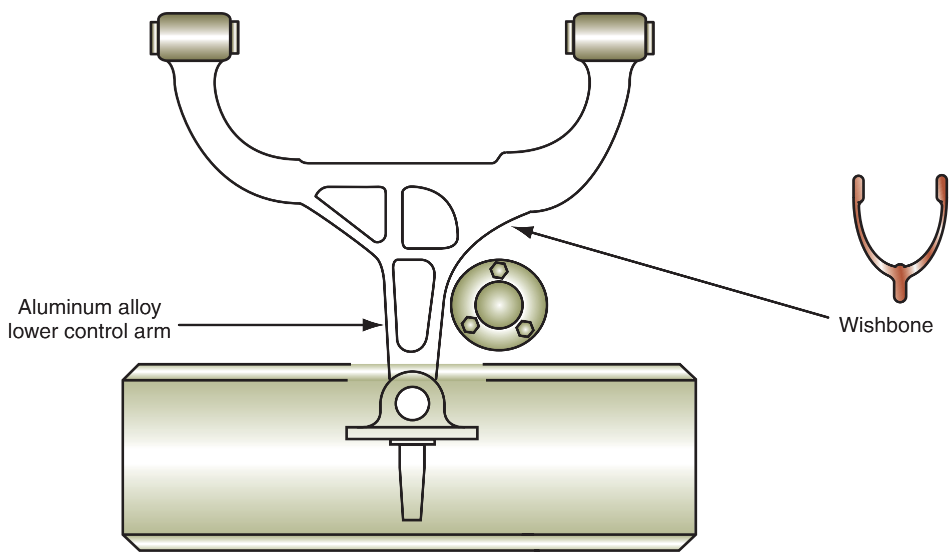

FIGURE 7-38 Double wishbone rear suspension.

by a cast aluminum subframe (Figure 7-39). This design also helps reduce vehicle weight and transmits suspension loads to the chassis at the most efficient locations.

Some independent rear suspension systems experience undesirable toe changes during wheel jounce and rebound. These toe changes cause vehicle instability during cornering and acceleration. In the double wishbone rear suspension system, the control arm design and the pivot locations on the rear toe control arm provide minimal change in toe-in during wheel jounce (Figure 7-40). This action results in extremely stable steering while cornering, accelerating, or driving on irregular road surfaces. The toe control arm may be lengthened

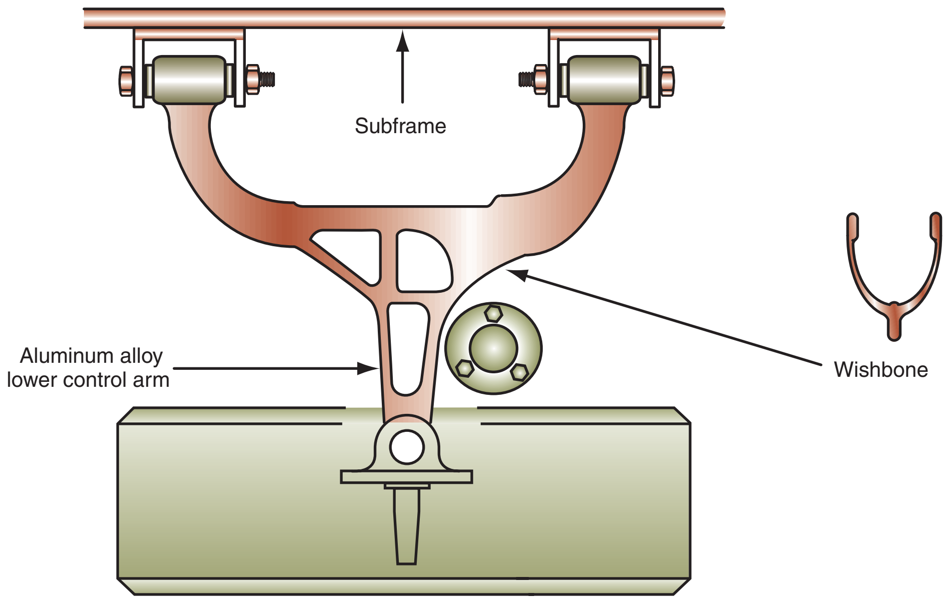

FIGURE 7-39 **Double wishbone rear suspension and subframe.**

or shortened to adjust rear wheel toe. An eccentric cam on the rear upper control arm bolt provides a rear wheel camber adjustment (Figures 7-41 and 7-42).

Independent Rear Suspension with Transverse Leaf Spring

Some cars have an independent rear suspension system with a transverse mono-leaf fiberglass spring. This type of spring is compact, lightweight, and corrosion-free. Dual trailing arms are connected rearward from the chassis to the knuckle on each side of the suspension, and spindle support rods are attached from the center of the suspension to the bottom of the knuckle. Tie rods are connected from the rear of the knuckle to the center of the suspension (Figure 7-43).

Other independent rear suspension systems have a multiple-leaf transversely mounted rear spring. In these suspension systems, heavy control arms extend rearward from the chassis

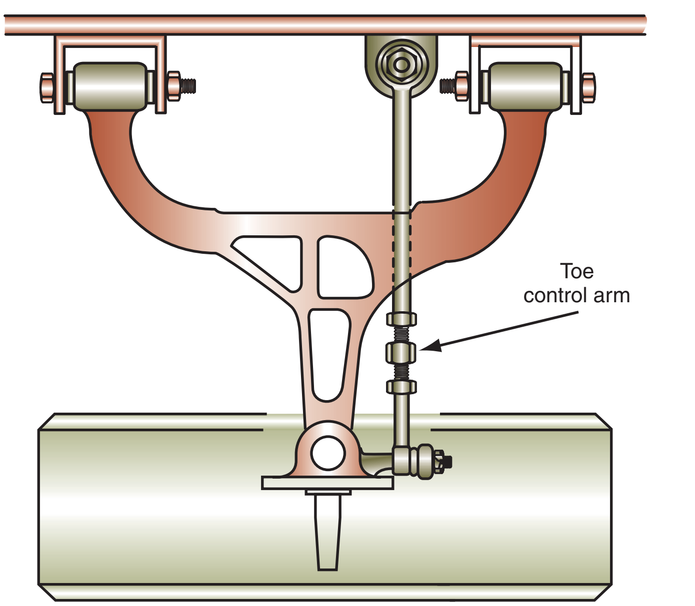

FIGURE 7-40 **Double wishbone rear suspension and toe control arm.**

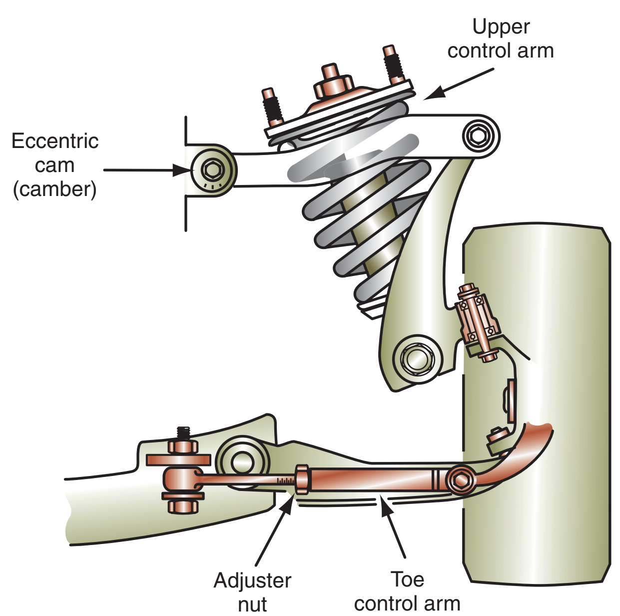

FIGURE 7-41 **Rear suspension camber and toe adjustments.**

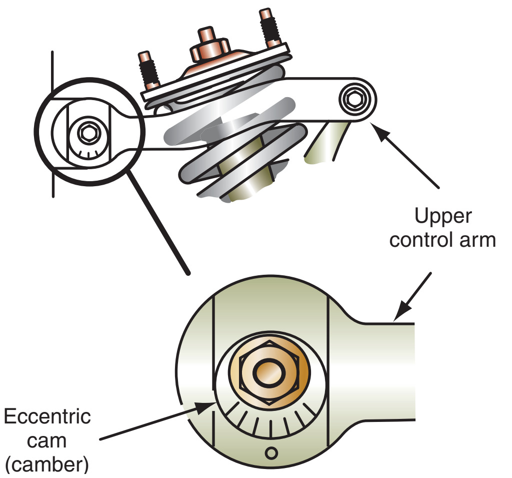

FIGURE 7-42 **Eccentric cam for camber adjustment on rear upper control arm bolt.**

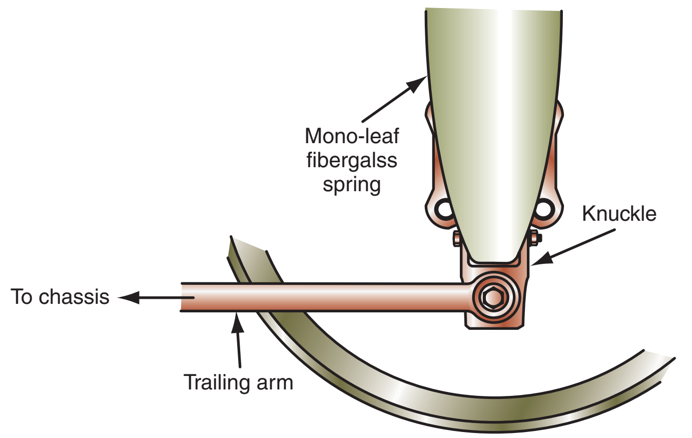

FIGURE 7-43 **Independent rear suspension with mono-leaf transverse fiberglass spring.**

to the knuckles, and strut rods are connected from the bottom of the knuckles to the center of the suspension. The shock absorbers are connected from the lower end of the knuckles to the chassis. A suspension member connects the differential housing to the chassis. All suspension component mounting locations are insulated with rubber bushings.

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Curb Riding Height

Regular inspection and proper maintenance of suspension systems is extremely important to maintaining vehicle safety. *The curb riding height is determined mainly by spring condition.* Other suspension components such as control arm bushings will affect curb riding height if they are worn. Since incorrect curb riding height affects most of the other suspension angles, this measurement is critical. The curb riding height must be measured at the vehicle manufacturer's specified location, which varies depending on the type of suspension system. When the vehicle is on a level floor or an alignment rack, measure the curb riding height from the floor to the manufacturer's specified location (Figure 7-44).

Caster angle is the tilt of an imaginary line through the center of the upper strut mount and ball joint in relation to the true vertical line through the center of the wheel and spindle when viewed from the side.

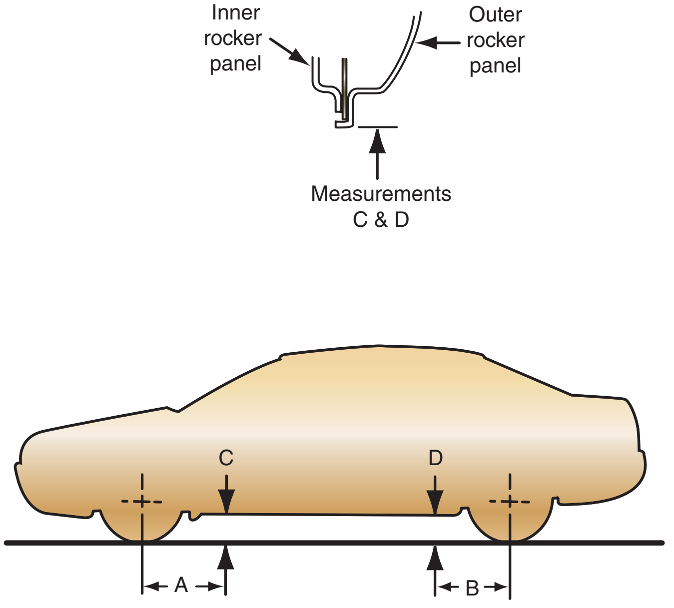


FIGURE 7-44 **Front and rear curb riding height measurement locations.**

Spring Sag, Curb Riding Height, and Caster Angle

Sagged springs cause insufficient curb riding height. Therefore, the distance is reduced between the rebound bumper and its stop. This distance reduction causes the bumper to hit the stop frequently with resulting harsh ride quality.

When both rear springs are sagged, the **caster angle** tilts excessively toward the rear of the vehicle. This type of angle is called positive caster. Rear spring sag and excessive positive caster increase steering effort and cause rapid steering wheel return after a turn is completed.

Summary

- A live-axle rear suspension is one in which the differential housing, wheel bearings, and brakes act as a unit.
- A live-axle rear suspension system provides good lateral stability, sway control, and steering characteristics, but this type of rear suspension causes increased tire wear with decreased ride quality and traction compared with other types of rear suspensions.
- Compared with other rear suspensions, the live-axle leaf spring suspension is more subject to axle tramp problems.
- In a live-axle leaf-spring rear suspension system, the leaf springs absorb differential torque and provide lateral control.
- In a live-axle coil-spring rear suspension system, the lower control arms absorb differential torque and the upper arms control lateral movement.
- Live-axle coil-spring rear suspension systems may have a tracking bar to control lateral movement.
- A semi-independent rear suspension has a limited amount of individual rear wheel movement provided by a steel U-section channel or crossmember.
- In an independent rear suspension, each rear wheel can move individually without affecting the opposite rear wheel.
- Compared with a live-axle rear suspension system, an independent rear suspension provides improved ride quality, steering control, tire life, and traction.
- In a MacPherson strut independent rear suspension, the coil springs are mounted on the struts.
- In a modified MacPherson strut independent rear suspension, the coil springs are mounted separately from the struts.
- In some independent rear suspension systems, the knuckle is positioned by a ball joint on the lower end and the strut on the upper end, and the coil spring is positioned between the lower control arm and the chassis.
- In a multilink independent rear suspension, the top of the knuckle is positioned by a rear upper link and a front upper link, and the lower end of the knuckle is positioned by a lower arm.
- Some RWD vehicles have an independent rear suspension with the differential connected through insulating mounts to the chassis.
- Some FWD and RWD vehicles have an independent rear suspension with a mono-leaf or multiple-leaf transversely mounted leaf spring.

Terms to Know

Amplitude
Asymmetrical leaf spring
Axle tramp
Axle windup
Braking and deceleration torque
Caster angle
Cycle
Double wishbone rear suspension system
Electronic vibration analyzer (EVA)
Five-link suspension
Frequency
Hertz
Independent rear suspension
Live-axle rear suspension system
Multilink independent rear suspension
Natural vibration frequencies
Rear suspension system
Rear wheel toe
Resonance
Semielliptical springs
Semi-independent rear suspension
Solid axle beam
Sprung weight
Symmetrical leaf spring
Track bar
Unsprung weight
Vibration

REVIEW QUESTIONS

Short Answer Essays

1. Describe a live-axle rear suspension system.
2. Explain the disadvantages of a live-axle leaf-spring rear suspension.
3. Describe the purpose of a leaf-spring shackle.
4. Explain the differential torque action during acceleration, and describe how this torque is absorbed in a live-axle coil-spring rear suspension.
5. Define axle tramp.
6. Describe the purpose of a tracking bar.
7. Explain the difference between a semi-independent and an independent rear suspension system.
8. Explain the advantages of an independent rear suspension compared with a live-axle rear suspension.
9. Describe the advantage of mounting the differential to the chassis in a RWD car with an independent rear suspension.
10. Describe the components that position the upper end of the knuckle in a multilink rear suspension.

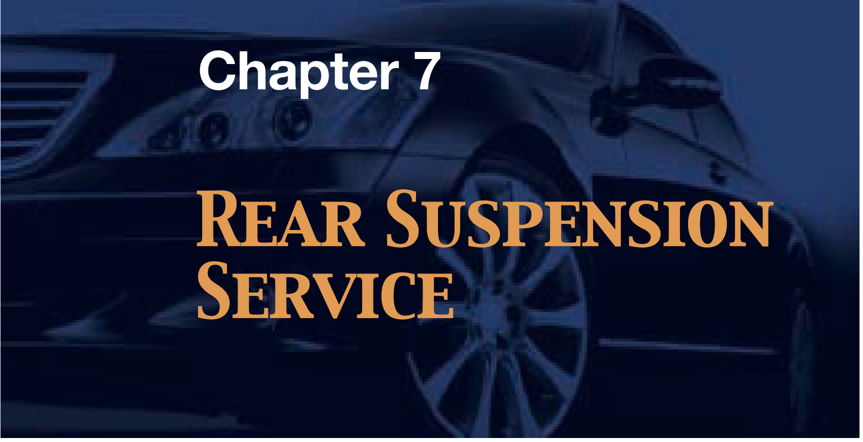
Fill-in-the-Blanks

1. A live-axle leaf-spring rear suspension provides excellent _______________ stability.
2. During braking and deceleration, the front of the differential is twisted _______________.
3. Axle tramp occurs during hard _______________.
4. In many live-axle coil-spring rear suspensions, the differential torque is absorbed by the trailing lower _______________ _______________.
5. In a modified MacPherson strut independent rear suspension, the coil-spring seat is located on the _______________ _______________.
6. In a multilink independent rear suspension, the rear suspension member supports the suspension and the _______________.
7. In some multilink rear suspension systems, the rubber mounting bushings between the suspension member and the chassis are _______________ in the fore/aft direction and _______________ in the lateral direction.
8. A fiberglass mono-leaf rear spring is compact, lightweight, and _______________ free.
9. When the rear springs are sagged, the caster angle on the front suspension becomes more _______________.
10. If the rear springs are sagged, the _______________ is increased.

MULTIPLE CHOICE

1. Rear axle tramp is caused by:
   A. Irregular road surfaces.
   B. A bent rear control arm.
   C. Engine torque transmitted through the drive shaft.
   D. Improper rear wheel alignment.
2. All of these statements about a live-axle leaf-spring rear suspension are true EXCEPT:
   A. During acceleration the front of the differential twists upward.
   B. The differential torque in a live-axle rear suspension is applied to the springs.
   C. While decelerating and braking, the front of the differential twists downward.
   D. This type of rear suspension has a small amount of unsprung weight.
3. Rear axle tramp occurs during:
   A. Hard acceleration.
   B. Deceleration.
   C. High speed driving.
   D. Cornering at high speed.
4. In a semi-independent rear suspension system, some individual wheel movement is provided by:
   A. The U-section channel and integral stabilizer bar.
   B. The struts.
   C. The trailing arms.
   D. The track bar and brace.

5. In a semi-independent rear suspension system:
   A. The track bar and brace absorb differential torque.
   B. The trailing arms prevent lateral wheel movement.
   C. The lower coil spring seats may be on the trailing arms.
   D. The lower end of the shock absorbers may be attached to the track bar.
6. In a MacPherson strut independent rear suspension system:
   A. The spring seats are positioned on the struts.
   B. The upper spring seat is positioned in a chassis support.
   C. The lower end of each strut is attached to the strut rod.
   D. The ends of the coil spring are in direct contact with the spring seats.
7. All of these statements about modified MacPherson strut suspension systems are true EXCEPT:
   A. The lower control arms prevent lateral wheel movement.
   B. The tie rods control fore-and-aft wheel movement.
   C. The strut is bolted to the lower end of the spindle.
   D. The upper strut mount is retained on top of the strut.
8. In an independent rear suspension with a lower control arm and ball joint:
   A. The ball joint is pressed into the tie rod.
   B. The strut is bolted to the top of the knuckle.
   C. The lower coil-spring seat is mounted on the strut.
   D. The suspension adjustment link is connected from the lower control arm to the chassis.
9. Sagged rear springs may cause:
   A. Slow steering wheel return after turning a corner.
   B. Decreased steering effort.
   C. Decreased positive caster on the front wheels.
   D. Harsh ride quality.
10. The adjustment link in a multilink rear suspension:
   A. Provides a rear wheel caster adjustment.
   B. Provides a rear wheel toe adjustment.
   C. Reduces fore-and-aft rear wheel movement.
   D. Absorbs engine torque transmitted through the drive shaft.



Chapter 7

Rear Suspension Service

Upon completion and review of this chapter, you should be able to:

- Diagnose rear suspension noises.
- Diagnose rear suspension sway and lateral movement.
- Measure and correct rear suspension curb riding height.
- Remove and replace rear coil springs.
- Inspect rear springs, insulators, and seats.
- Inspect strut or shock absorber bushings and upper mount, and replace strut cartridge.
- Remove, inspect, and replace lower control arms.
- Inspect, remove, and replace rear ball joints.
- Inspect, remove, and replace suspension adjustment links.
- Diagnose, remove, and replace rear leaf springs.
- Diagnose, remove, and replace stabilizer bars.
- Diagnose, remove, and replace track bars.
- Inspect, remove, and replace tie-rods.

Rear suspension system diagnosis and service is extremely important to maintain vehicle safety, ride quality, and tire life. Many rear suspension components may create a safety hazard if they are not serviced properly. For example, if wheel nuts or spindle nuts are not tightened properly, a wheel assembly may come off the vehicle with disastrous results. Improper rear suspension curb riding height, worn struts or shock absorbers, and sagged or broken springs will result in harsh ride quality. Rear wheel toe and camber must be adjusted to specifications to provide normal tire tread life.

BASIC TOOLS

Basic technician's tool set

Service manual

Machinist's rule

Floor jack

Safety stands

Transmission jack

Foot-pound torque wrench

Pry bar

Diagnosis of Ride Harshness

When diagnosing a ride harshness condition, check these measurements and components:

1. Curb riding height—insufficient curb riding height causes ride harshness
2. Excessive vehicle load
3. Worn shock absorbers or struts
4. Broken or weak springs
5. Worn suspension bushings, such as strut mounts, control arm bushings, and shock absorber mounting bushings
6. Wheel alignment—excessive positive caster on front wheels causes ride harshness

Noise Diagnosis

A squeaking noise in the rear suspension may be caused by a suspension bushing or a defective strut or shock absorber.

If a rattling noise occurs in the rear suspension, check these components:

1. Worn or missing suspension bushings, such as control arm bushings, track bar bushings, stabilizer bar bushings, trailing arm bushings, and strut rod bushings
2. Worn strut or shock absorber bushings or mounts
3. Defective struts or shock absorbers
4. Broken springs or worn spring insulators
5. Broken exhaust system hangers or improperly positioned exhaust system components

Special tools can be used to locate noises at any location on the vehicle. A ChassisEar tool has six clamp-on sensors that are miniature microphones (Figure 7-1). These six sensors are connected to a switchbox that is also connected to a headset worn by the technician. The technician can rotate the switch on the switchbox to connect any sensor to the headset. The sensors can be mounted on various suspected noise sources. When the control on the switchbox is rotated, the technician can determine which sensor is connected to the noise source.

Body sway is leaning of the chassis to one side.

An electronic stethoscope can be used to locate the source of a noise. This tool has one pickup that is placed on or near a suspected noise source. The pickup is connected to an amplifier box, and the headset is also connected to this box (Figure 7-2). When the pickup is placed on the source of a noise, the noise is amplified in the headset.

SERVICE TIP: Proper curb riding height must be maintained to provide normal steering quality and tire wear.

Sway and Lateral Movement Diagnosis

Excessive **body sway,** or roll, on road irregularities may be caused by a weak stabilizer bar or loose stabilizer bar bushings. If lateral movement is experienced on the rear of the chassis, the track bar or track bar bushings may be defective. Lateral movement is sideways movement.

Curb Riding Height Measurement

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Regular inspection and proper maintenance of suspension systems are extremely important to maintaining vehicle safety. The curb riding height is determined mainly by spring condition. Other suspension components, such as control arm bushings, affect curb riding height if they are worn. *Since incorrect curb riding height affects most of the other suspension angles, this measurement is critical.* Reduced rear suspension height increases steering effort and causes rapid steering wheel return after turning a corner. Harsh riding occurs when the curb riding height is less than specified. The curb riding height must be measured at the vehicle

FIGURE 7-1 **ChassisEar tool for locating noise sources.**

FIGURE 7-2 **Electronic stethoscope.**

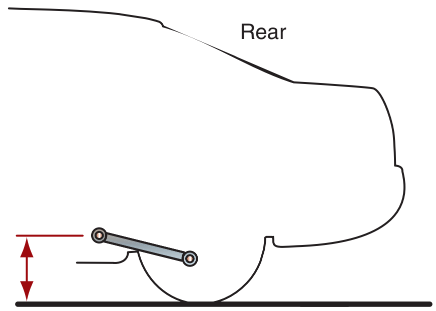


FIGURE 7-3 **Curb riding height measurement, rear suspension.**

manufacturer's specified location, which varies depending on the type of vehicle and suspension system. On some vehicles, the curb riding height on the rear suspension is measured from the floor to the center of the strut rod mounting bolt when the vehicle is on a level floor or an alignment rack (Figure 7-3). Photo Sequence 11 shows a typical procedure for measuring front and rear curb riding height.

Rear Strut, Coil Spring, and Upper Mount Diagnosis and Service

WARNING: When the rear coil springs are mounted on the struts, never loosen the upper strut nut until all the spring tension is removed from the upper support with a spring compressor. If this nut is removed with spring tension on the upper support, the spring tension turns the spring and the upper support into a dangerous projectile, which may cause serious personal injury and/or property damage.

Weak springs cause harsh riding and reduced curb riding height. Broken springs or spring insulators cause a rattling noise while driving on road irregularities. Worn-out struts or shock absorbers cause excessive chassis oscillations and harsh riding. (Refer to Chapter 5 for strut and shock absorber service.) Loose or worn strut or shock absorber bushings cause a rattling noise on road irregularities. The rear coil spring removal and replacement procedure varies depending on the type of rear suspension system. Always follow the vehicle manufacturer's recommended procedure in the service manual.

The following is a typical rear strut and spring removal and replacement procedure on a MacPherson strut independent rear suspension system with the coil springs mounted on the struts:

1. Remove the rear seat and the package trim tray (Figure 7-4).
2. Remove the wheel cover, and loosen the wheel nuts.
3. Lift the vehicle with a floor jack, and lower the chassis onto safety stands so the rear suspension is allowed to drop downward.
4. Place a floor jack lift pad under the rear spindle on the side where the strut and spring removal is taking place. Raise the floor jack to support some of the suspension system weight (Figure 7-5).
5. Remove the rear wheel, disconnect the nut from the small spring in the lower arm (Figure 7-6), and remove the brake hose and antilock brake system (ABS) wire from the strut (Figure 7-7).
6. Remove the stabilizer bar link from the strut (Figure 7-8), and loosen the strut-to-spindle mounting bolts (Figure 7-9).
7. Remove the three upper support nuts under the package tray trim (Figure 7-10), and lower the floor jack to remove the strut from the knuckle (Figure 7-11). Remove the strut from the chassis.

SERVICE TIP: If the plastic coating on a coil spring is chipped, the spring may break prematurely. The spring may be taped in the compressing tool contact areas to prevent chipping.

PHOTO SEQUENCE 11

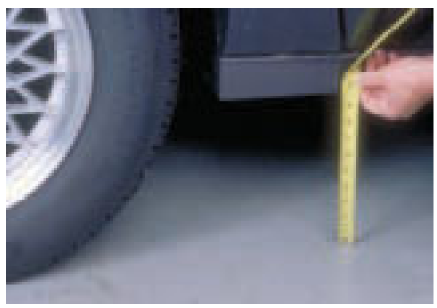
Typical Procedure for Measuring Front and Rear Curb Riding Height

P11-1 **Check the trunk for extra weight.**

P11-2 **Check the tires for normal inflation pressure.**

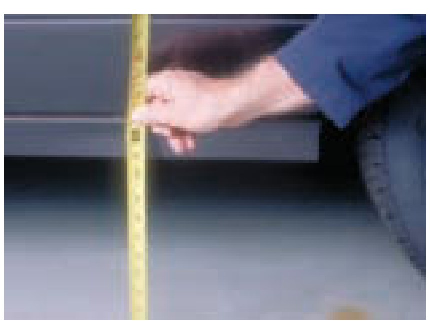
P11-3 **Park the car on a level shop floor or alignment rack.**

P11-4 **Find the vehicle manufacturer's specified curb riding height measurement locations in the service manual.**



P11-5 **Measure and record the right front curb riding height.**

P11-6 **Measure and record the left front curb riding height.**



P11-7 **Measure and record the right rear curb riding height.**

P11-8 **Measure and record the left rear curb riding height.**

P11-9 **Compare the measurement results to the specified curb riding height in the service manual.**

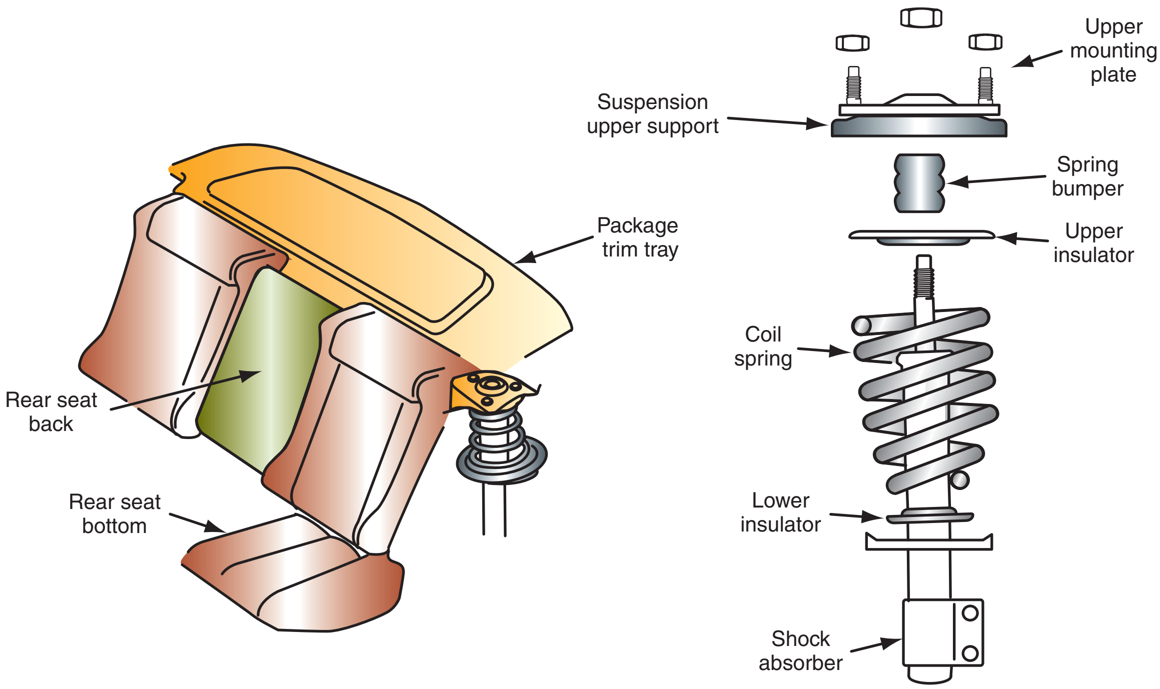


FIGURE 7-4 **Rear suspension with rear seat and package trim tray.**

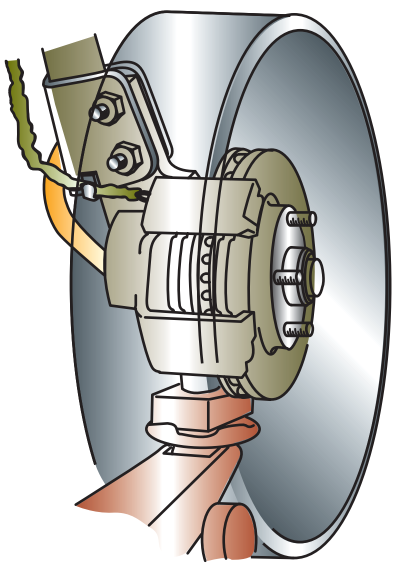


FIGURE 7-5 **Floor jack supporting some of the rear suspension weight.**

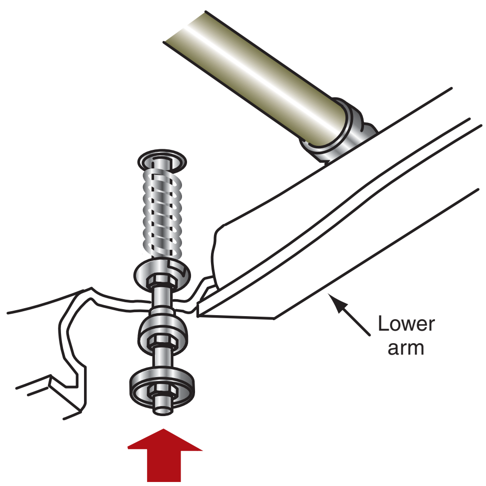


FIGURE 7-6 **Disconnecting nut from small spring in the lower arm.**

8. Following the vehicle or equipment manufacturer's recommended procedure, install a spring compressing tool on the coil spring, and tighten the tool until all the spring tension is removed from the upper support (Figure 7-12).
9. Operate the compressing tool to remove all the spring tension from the upper strut mount and then remove the strut rod nut (Figure 7-13).
10. Remove the strut rod nut, upper support, and upper insulator.
11. Remove the strut from the lower end of the spring.
12. If the spring is to be replaced, rotate the compressing tool handle until all the spring tension is removed from the compressing tool, and then remove the spring from the tool.

SPECIAL TOOLS
Coil-spring compressor

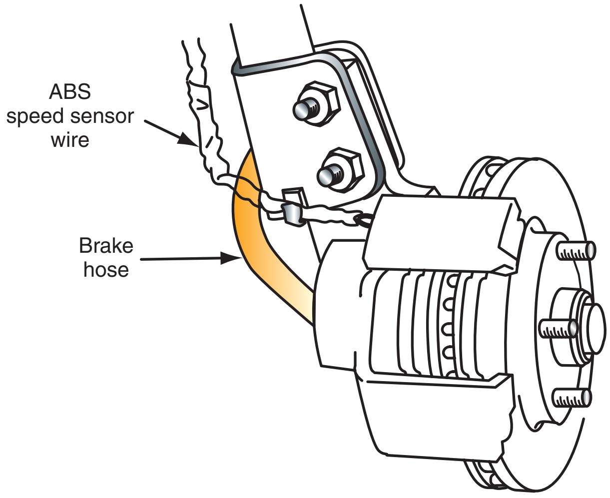


FIGURE 7-7 **Disconnecting brake hose and ABS wire from the rear strut.**

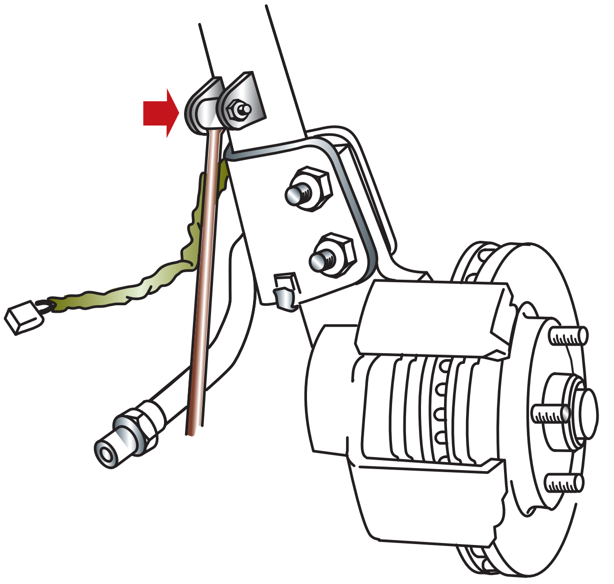


FIGURE 7-8 **Removing stabilizer bar from the rear strut.**

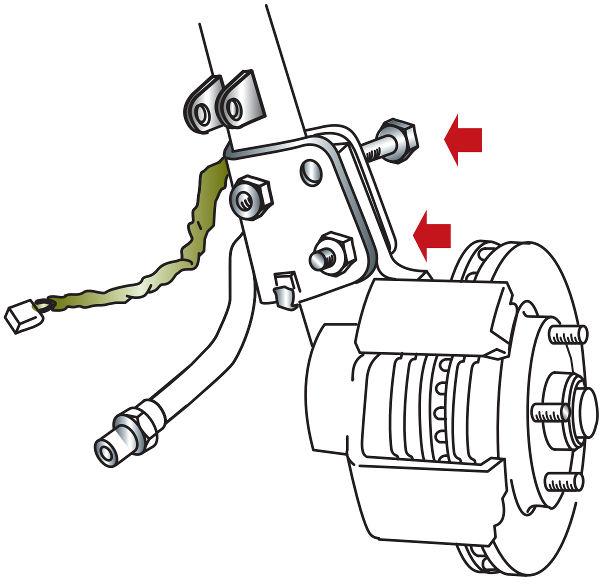


FIGURE 7-9 **Loosening strut-to-rear spindle bolts.**

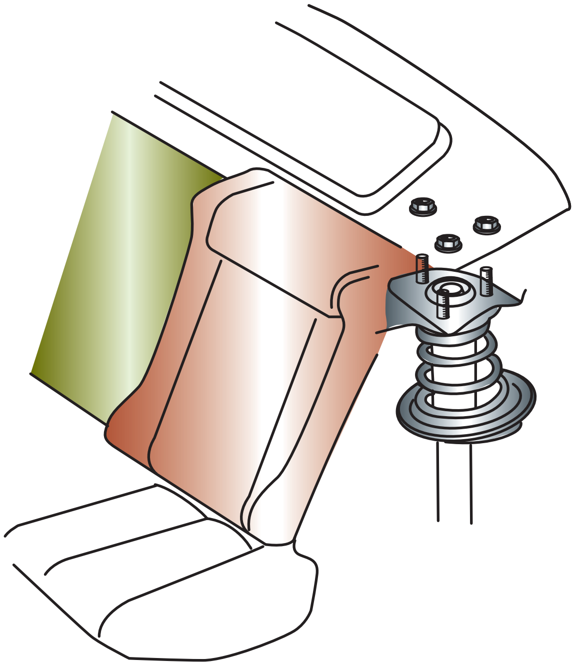


FIGURE 7-10 **Removing upper mount nuts.**

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13. Inspect the lower insulator and spring seat on the strut (Figure 7-14). If the spring seat is warped or damaged, replace the strut. A new cartridge may be installed in some rear struts. (The strut cartridge replacement procedure is explained in Chapter 5.)
14. Visually inspect the upper mount, insulator, and spring bumper. If any of these components are damaged, worn, or distorted, replacement is necessary. Worn upper mounts and insulators or damaged spring seats cause suspension noise while driving on road irregularities. Assemble the spring bumper, upper mount, and insulator (Figure 7-15), and then compress the coil spring in the compressing tool. Assemble the strut and related components into the spring (Figure 7-16). Tighten all fasteners to the specified torque. Photo sequence 12 illustrates the proper procedure for removing a rear strut and spring.

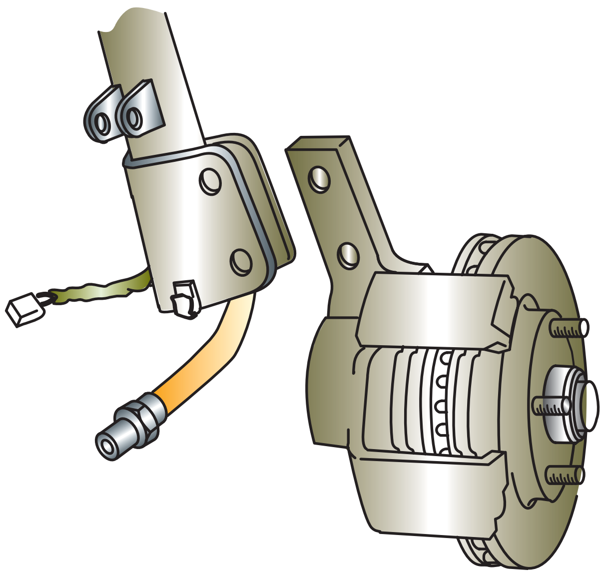


FIGURE 7-11 **Removing the strut from the rear spindle.**

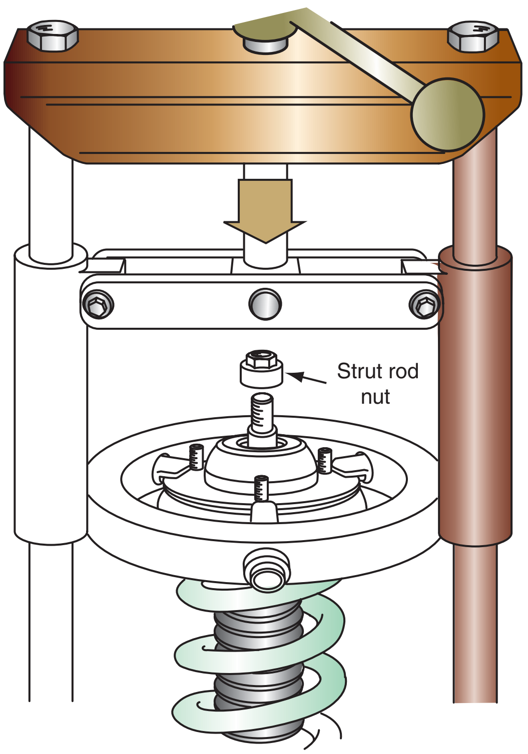


FIGURE 7-12 **A spring compressing tool is used to compress the coil spring.**

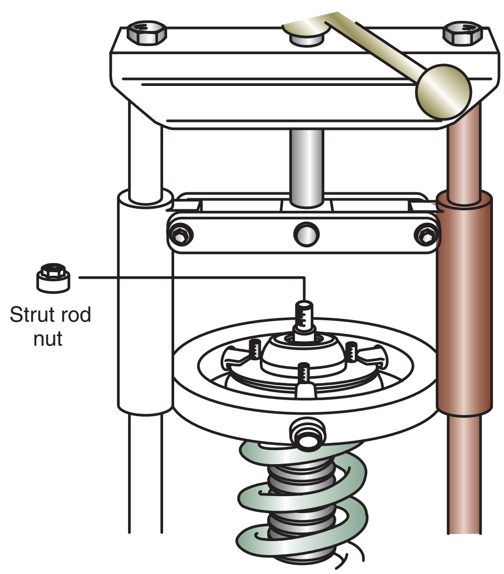


FIGURE 7-13 **After the compressing tool is operated to remove all the spring tension, remove the strut rod nut.**

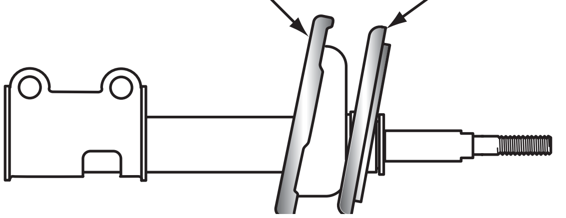


FIGURE 7-14 **Inspecting lower spring seat and insulator.**

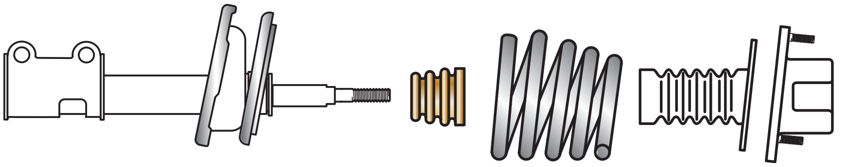


FIGURE 7-15 **Assembly of rear strut, spring bumper, spring, upper mount, and insulator.**

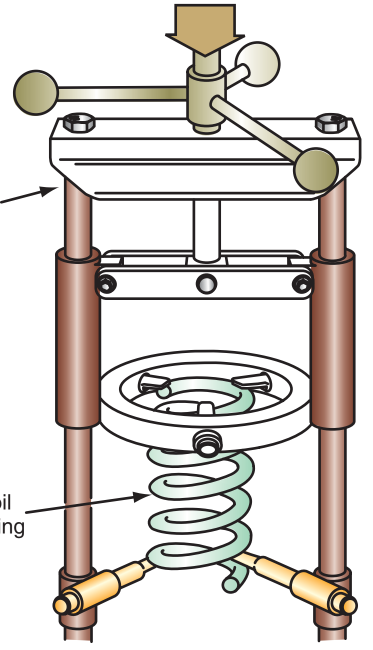


FIGURE 7-16 **Compressing the coil spring in the compressing tool prior to strut-and-spring assembly.**

> **CUSTOMER CARE: When talking to customers, always remember the two Ps, pleasant and polite. There may be many days when we do not feel like being pleasant and polite. Perhaps we have several problem vehicles in the shop with symptoms that are difficult to diagnose and correct. Some service work may be behind schedule, and customers may be irate because their vehicles are not ready on time. However, we should always remain pleasant and polite with customers. Our attitude does much to make the customer feel better and realize their business is appreciated. A customer may not feel very happy about an expensive repair bill, but a pleasant attitude on our part may help improve the customer's feelings. When the two Ps are remembered by service personnel, customer relations are enhanced, and the customer will return to the shop. Conversely, if service personnel have a grouchy, indifferent attitude, the customer may be turned off and take his or her business to another shop.**

LOWER CONTROL ARM AND BALL JOINT DIAGNOSIS AND REPLACEMENT

Wear indicators show ball joint wear by the position of the grease fitting in the ball joint.

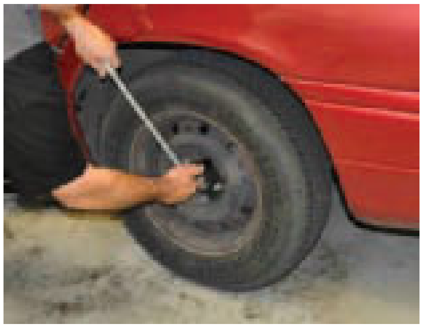
Worn bushings on the lower control arms may cause incorrect rear wheel camber or toe, which results in rear tire wear and steering pull. Bent lower control arms must be replaced. When ball joints with **wear indicators** are in normal condition, there is 0.050 in. (1.27 mm) between the grease nipple shoulder and the cover. If the ball joint is worn, the grease nipple shoulder is flush with or inside the cover (Figure 7-17). A worn ball joint causes improper rear wheel toe and/or camber, which may result in tire tread wear or steering pull.

The lower control arm removal and replacement procedure varies depending on the vehicle and the type of suspension. Always follow the vehicle manufacturer's recommended procedure in the service manual.

The following is a typical lower control arm removal procedure:

1. Lift the vehicle on a hoist with the chassis supported on the hoist and the control arms dropped downward. The vehicle may be lifted with a floor jack, and the chassis supported on safety stands.
2. Remove the tire-and-wheel assembly.

Typical Procedure for Removing a Rear Strut-and-Spring Assembly on a Front-Wheel-Drive Car



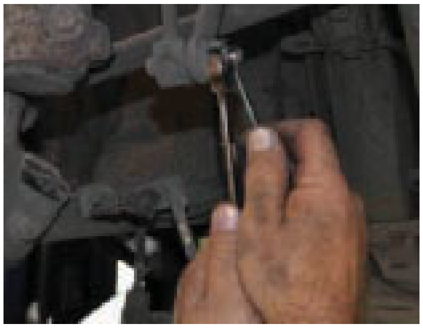
P12-1 **Remove the left rear wheel cover, and loosen the wheel nuts on the left rear wheel.**

P12-2 **Raise the vehicle on a frame-contact lift and chalk mark one of the left rear wheel studs in relation to the wheel, and remove the wheel nuts followed by the wheel-and-tire assembly.**

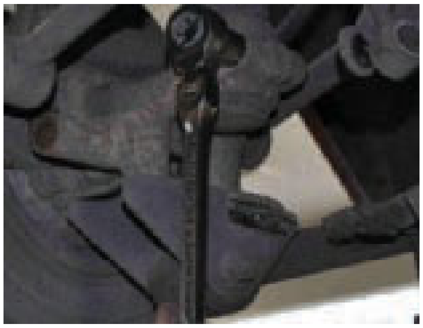
P12-3 **Remove the left rear brake caliper, and use a piece of wire to suspend the caliper from a chassis member. Do not allow the caliper to hang from the flexible brake hose.**

P12-4 **If the vehicle is equipped with antilock brakes, remove the left rear speed sensor wire, routing tube, and bracket from the trailing arm.**

P12-5 **Remove both forward and rearward lateral lower link-to-spindle attaching bolts by installing a thin open-end wrench on the hex of the attaching link stud to prevent the stud from turning and then remove the lateral link-to-spindle attaching bolts.**



P12-6 **Use an open-end wrench to hold the left rear stabilizer bar attaching link stud from turning, and remove the stabilizer bar attaching link nut. Disconnect the stabilizer bar from the attaching link stud.**



P12-7 **Remove the nut from the strut-to-spindle pinch bolt, and remove the pinch bolt.**

P12-8 **Tap a center punch into the slot in the lower end of the strut to spread the strut opening slightly. Be sure the inner end of the punch does not contact and puncture the strut.**

P12-9 **Use a hammer to tap the top of the spindle and drive it downward off the end of the strut. Allow the left rear spindle and assembled components to hang from the trailing arm.**

PHOTO SEQUENCE 12 (CONTINUED)

Typical Procedure for Removing a Rear Strut-and-Spring Assembly on a Front-Wheel-Drive Car

P12-10 **Lower the vehicle on the lift so the disconnected components on the left rear suspension and the other tires are a short distance off the shop floor. Open the trunk and remove the dust cap on top of the left rear strut opening. Loosen the left rear strut mounting nuts.**

P12-11 **Have a coworker hold the left rear strut-and-spring assembly and remove the strut mounting nuts. Remove the left rear strut from the vehicle.**

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SPECIAL TOOLS

Lower control arm support tool

3. Remove the stabilizer bar from the knuckle bracket.
4. Remove the parking brake cable retaining clip from the lower control arm.
5. If the car has electronic level control (ELC), disconnect the height sensor link from the control arm.
6. Install a special tool to support the lower control arm in the bushing areas (Figure 7-18).
7. Place a transmission jack under the special tool and raise the jack enough to remove the tension from the control arm bushing retaining bolts. If the car was lifted with a floor jack and supported on safety stands, place a floor jack under the special tool.
8. Place a safety chain through the coil spring and around the lower control arm.
9. Remove the bolt from the rear control arm bushing.
10. Be sure the jack is raised enough to relieve the tension on the front bolt in the lower control arm and remove this bolt.
11. Lower the jack slowly and allow the control arm to pivot downward. When all the tension is released from the coil spring, remove the safety chain, coil spring, and insulators.

Check the coil spring for distortion and proper free length. If the spring has a vinyl coating, check this coating for scratches and nicks. Check the spring insulators for cracks and wear.

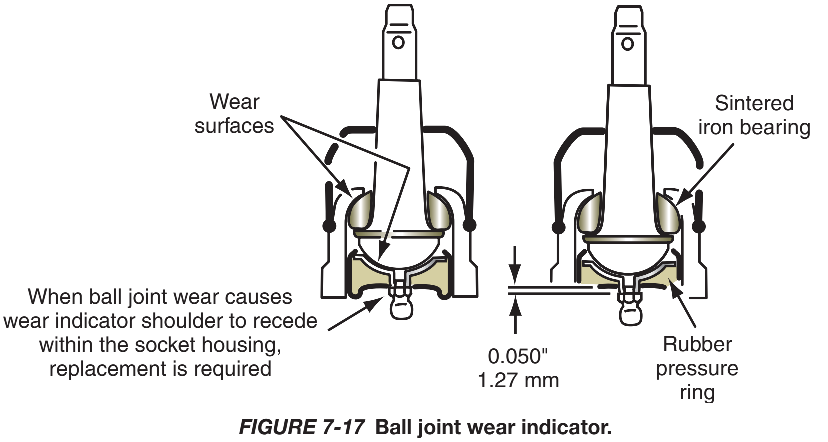

FIGURE 7-17 **Ball joint wear indicator.**

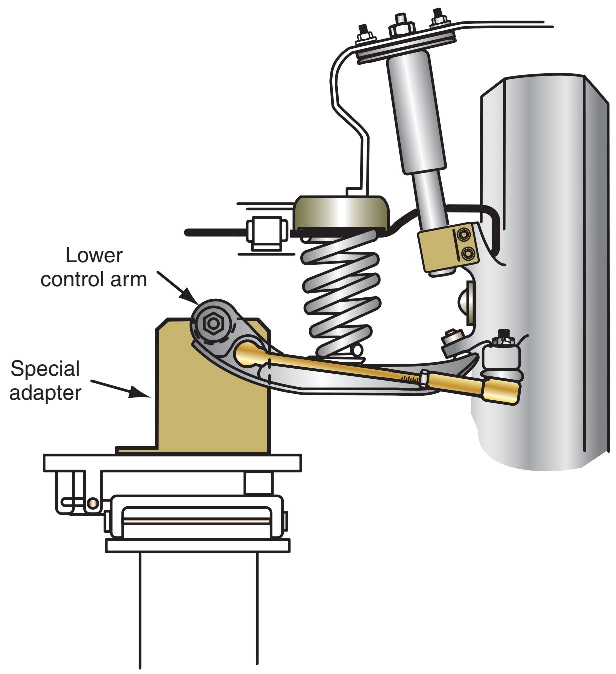

FIGURE 7-18 **Special tool installed to support the inner end of the lower control arm.**

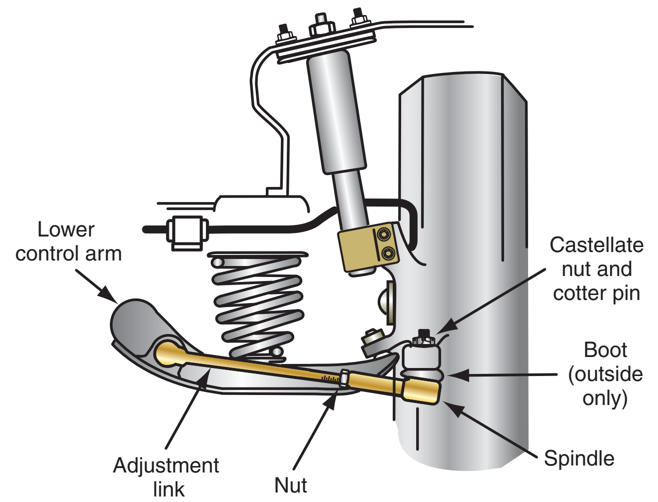

FIGURE 7-19 **Removing the suspension adjustment link from the lower control arm.**

After the coil spring is removed, follow these steps to remove the lower control arm:

1. Remove the nut on the inner end of the **suspension adjustment link,** and disconnect this link from the lower control arm (Figure 7-19).
2. Remove the cotter pin from the ball joint nut, and loosen, but do not remove, the nut from the ball joint stud.
3. Use a special ball joint removal tool to loosen the ball joint in the knuckle.
4. Remove the ball joint nut and the lower control arm (Figure 7-20).

Check the lower control arm for bends, distortion, and worn bushings. A special ball joint pressing tool is used to press the ball joint from the lower control arm (Figure 7-21), and the same pressing tool with different adapters is used to press the new ball joint into the control arm (Figure 7-22).

Remove the nut and cotter pin on the outer end of the suspension adjustment link, and use a special puller to remove this link from the knuckle (Figure 7-23). Remove the suspension adjustment link and inspect the joints. If the joints are loose or the seals are damaged, joint replacement is necessary. The joint studs must fit snugly in the knuckle and lower

A **suspension adjustment link** may be connected from the rear knuckle to the lower control arm to adjust rear wheel toe.

CAUTION:
When disconnecting a linkage joint, such as the ends of the suspension adjustment link, do not use a wedge-type tool between the joint and the attached part. This method of joint removal may damage the joint seal.

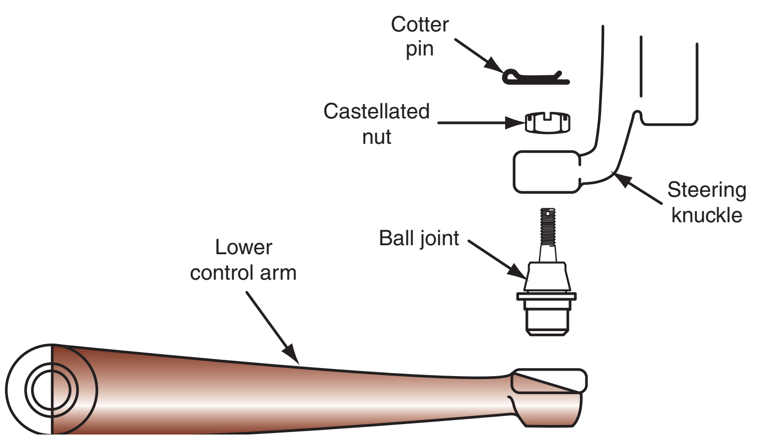

FIGURE 7-20 **Removing the lower control arm and ball joint.**

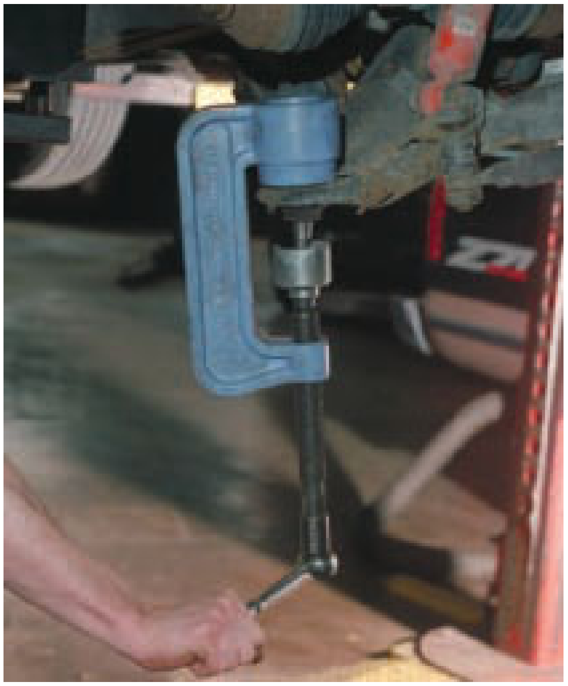

FIGURE 7-21 **Removing the ball joint from the lower control arm.**

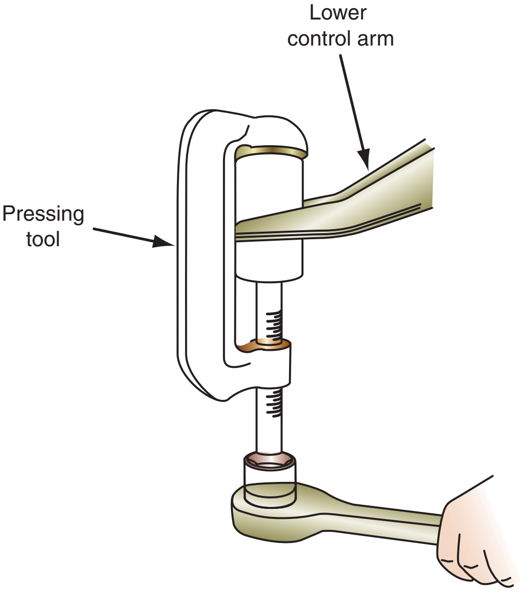

FIGURE 7-22 **Installing the ball joint in the lower control arm.**

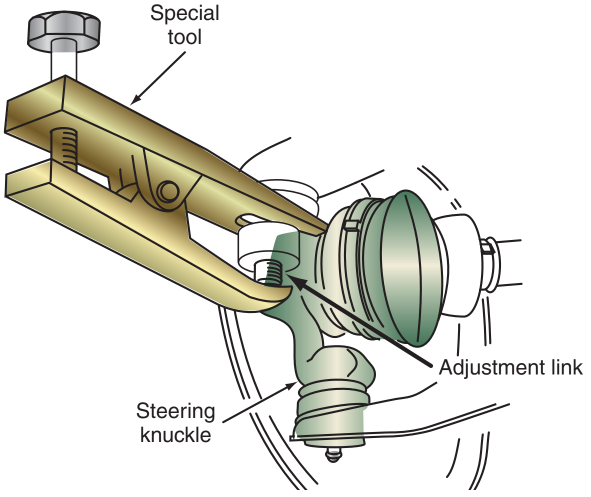

FIGURE 7-23 **Removing the suspension adjustment link from the knuckle.**

control arm openings. When the joint studs are worn, joint replacement is necessary, and worn stud openings in the knuckle or lower control arm require component replacement.

Follow this procedure to install the lower control arm and spring:

1. Install the ball joint stud in the knuckle and install the nut on the ball joint stud. Tighten the ball joint nut to the specified torque, and then tighten the nut an additional 2/3 turn. If necessary, tighten the nut slightly to align the nut castellations with the cotter pin hole in the ball joint stud, and install the cotter pin.
2. Snap the upper insulator on the coil spring. Install the lower spring insulator and the spring in the lower control arm (Figure 7-24).
3. Be sure the top of the coil spring is properly positioned in relation to the front of the vehicle (Figure 7-25).

SPECIAL TOOLS

Ball joint stud removal tool

Ball joint pressing tool

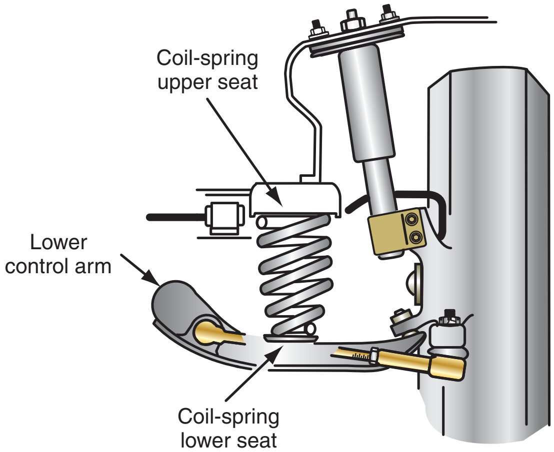

FIGURE 7-24 **Installing the spring and insulators.**

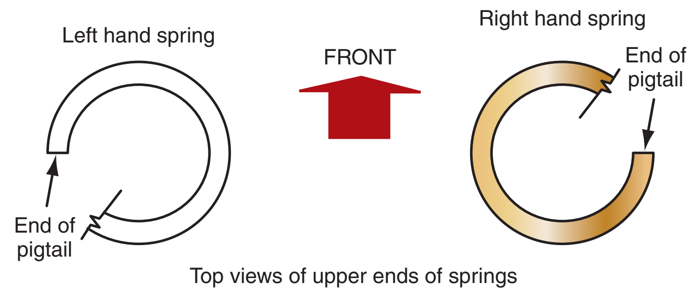

FIGURE 7-25 **Proper location of upper coil spring ends in relation to the front of the vehicle.**

4. Install the special tool on the inner ends of the control arm, and place the transmission jack under the special tool.
5. Slowly raise the transmission jack until the control arm bushing openings are aligned with the openings in the chassis.
6. Install the bolts and nuts in the inner ends of the control arm. Do not torque these bolts and nuts at this time.
7. Install the stabilizer-bar-to-knuckle bracket and tighten the fasteners to the specified torque.
8. Install the parking brake retaining clip.
9. If the vehicle has ELC, install the height sensor link, and tighten the fastener to the specified torque.
10. Install the suspension adjustment link and tighten the retaining nuts to the specified torque. Install cotter pins as required.
11. Remove the transmission jack and install the tire-and-wheel assembly.
12. Lower the vehicle onto the floor and tighten the wheel hub nuts and lower control arm bolts and nuts to the specified torque.

SPECIAL TOOLS

Suspension adjustment link removal tool

CAUTION:

Never loosen a ball joint nut to install a cotter pin, because this action causes improper torquing of the nut.

Rear Leaf-Spring Diagnosis and Replacement

This leaf-spring discussion applies to multiple-leaf springs on rear suspension systems that have two springs mounted longitudinally in relation to the chassis. Many leaf springs have plastic **spring silencers** between the spring leafs. If these silencers are worn out, creaking and squawking noises are heard when the vehicle is driven over road irregularities at low speeds.

When the silencers require checking or replacement, lift the vehicle with a floor jack and support the frame on safety stands so the rear suspension moves downward. With the vehicle weight no longer applied to the springs, the spring leafs may be pried apart with a pry bar to remove and replace the silencers.

Worn shackle bushings, brackets, and mounts cause excessive chassis lateral movement and rattling noises. With the normal vehicle weight resting on the springs, insert a pry bar between the rear outer end of the spring and the frame. Apply downward pressure on the bar and observe the rear shackle for movement. Shackle bushings, brackets, or mounts must be replaced if there is movement in the shackle. The same procedure may be followed to check the front bushing in the main leaf. A broken spring center bolt may allow the rear axle assembly to move rearward on one side. This movement changes rear wheel tracking, which results in handling problems, tire wear, and reduced directional stability. Sagged rear springs reduce the curb riding height. Spring replacement is necessary if the springs are sagged.

CAUTION:

The pivot bolts and nuts in the inner ends of the lower control arm must be tightened to the specified torque with the vehicle weight supported on the wheels and the suspension at normal curb height. Failure to follow this procedure may adversely affect ride quality and steering characteristics.

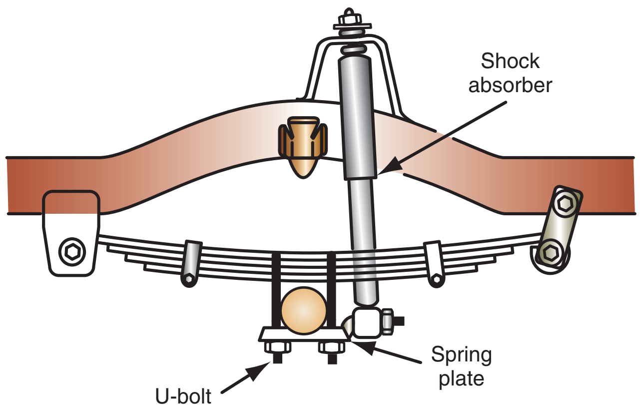

FIGURE 7-26 **Leaf-spring rear suspension.**

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When rear leaf-spring replacement is necessary, proceed as follows:

1. Lift the vehicle with a floor jack and place safety stands under the frame. Lower the vehicle weight onto the safety stands, and leave the floor jack under the differential housing to support the rear suspension weight.
2. Remove the nuts from the spring U-bolts, and remove the U-bolts and lower spring plate (Figure 7-26). The spring plate may be left on the rear shock absorber and moved out of the way.
3. Be sure the floor jack is lowered sufficiently to relieve the vehicle weight from the rear springs.
4. Remove the rear shackle nuts, plate, shackle, and bushings.
5. Remove the front spring mounting bolt and remove the spring from the chassis. Check the spring center bolt to be sure it is not broken.
6. Check the front hanger, bushing, and bolt, and replace as necessary.
7. Check the rear shackle, bushings, plate, and mount; replace the worn components.
8. Reverse steps 1 through 5 to install the spring. Tighten all bolts and nuts to the specified torque.

Spring silencers are plastic spacers mounted between the spring leafs to reduce spring noise.

Track Bar Diagnosis and Replacement

Directional stability refers to the tendency of the vehicle steering to remain in the straight-ahead position when driven straight ahead on a reasonably smooth, level road surface.

Some rear suspension systems have a track bar to control **lateral chassis movement**. Rubber mounting bushings insulate the track bar from the chassis components. Worn track bar mounts and bushings may cause rattling and excessive lateral chassis movement.

When the track bar is inspected, lift the vehicle on a hoist or floor jack with the rear suspension in the normal riding height position. If the vehicle is lifted with a floor jack, place safety stands under the rear axle to support the vehicle weight. Grasp the track bar firmly and apply vertical and horizontal force. If there is movement in the track bar mountings, track bar, or bushing, replacement is essential (Figure 7-27).

Lateral chassis movement refers to sideways movement.

Another track bar checking method is to leave the vehicle on the shop floor and observe the track bar mounts as an assistant applies side force to the chassis or rear bumper. If there is lateral movement in the track bar bushings or brackets, replace the bushings and check the bracket bolts. Bent track bars must be replaced.

When the track bar is replaced, remove the mounting bolts, bushings, grommets, and track bar. Inspect the mounting bolt holes in the chassis for wear. After the track bar is installed with the proper grommets and bushings, tighten the mounting bolts to the specified torque.

Stabilizer Bar Diagnosis and Service

A stabilizer bar may be referred to as a sway bar.

Worn stabilizer bar mounting bushings, grommets, or mounting bolts cause a rattling noise as the vehicle is driven on irregular road surfaces. A weak stabilizer bar or worn bushings and grommets cause harsh riding and excessive body sway while driving on irregular road

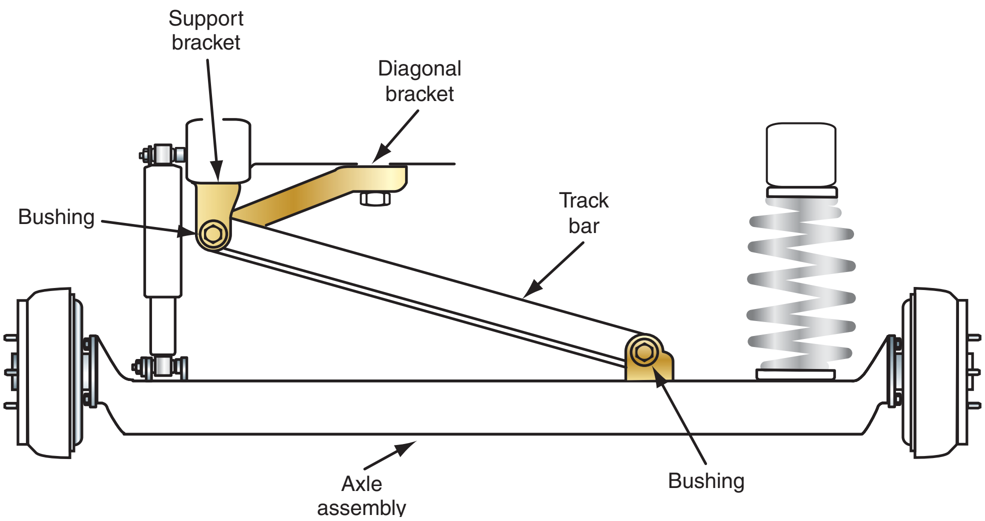

FIGURE 7-27 **Checking track bar bushings.**

surfaces. Worn or very dry stabilizer bar bushings may cause a squeaking noise on irregular road surfaces. All stabilizer bar components should be visually inspected for wear. Stabilizer bar removal and replacement procedures vary depending on the vehicle. Always follow the vehicle manufacturer's recommended procedure in the service manual.

SERVICE TIP: On rear suspension systems with an inverted U-channel, the stabilizer bar inside the U-channel sometimes breaks away where it is welded to the end plate in the U-channel. This results in a rattling, scraping noise when the car is driven over road irregularities.

Following is a typical rear stabilizer bar removal and replacement procedure:

1. Lift the vehicle on a hoist and allow both sides of the rear suspension to drop downward as the vehicle chassis is supported on the hoist.
2. Remove the mounting bolts at the outer ends of the stabilizer bar and remove the bushings, grommets, brackets, or spacers (Figure 7-28).
3. Remove the mounting bolts in the center area of the stabilizer bar.
4. Remove the stabilizer bar from the chassis.
5. Visually inspect all stabilizer bar components, such as bushings, bolts, and spacer sleeves. Replace the stabilizer bar, grommets, bushings, brackets, or spacers as required. Split bushings may be removed over the stabilizer bar. Bushings that are not split must be pulled from the bar.
6. Reverse steps 2 through 4 to install the stabilizer bar. Make sure all stabilizer bar components are installed in the original position, and tighten all fasteners to the specified torque.

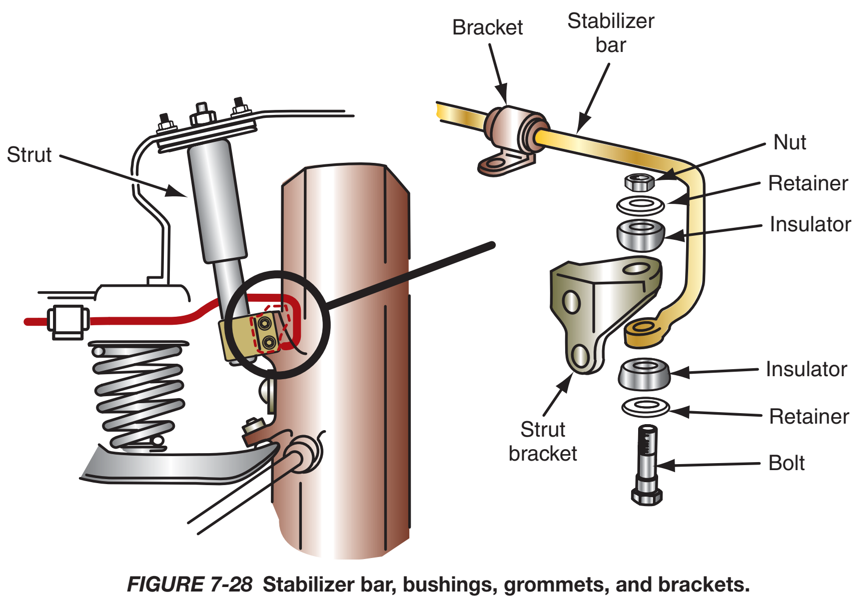

FIGURE 7-28 **Stabilizer bar, bushings, grommets, and brackets.**

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Rear Suspension Tie Rod Inspection and Replacement

Rear tie-rods should be inspected for worn grommets, loose mountings, and bent conditions. Loose tie-rod bushings or a bent tie-rod will change the rear wheel tracking and result in reduced directional stability. Worn tie-rod bushings also cause a rattling noise on road irregularities. When the rear tie-rod is replaced, remove the front and rear rod mounting nuts. The lower control arm or rear axle may have to be pried rearward to remove the tie-rod. Inspect the tie-rod grommets and mountings for wear, and replace parts as required. When the tie-rod is reinstalled, tighten the mounting bolts to specifications, and measure the rear wheel toe.

TABLE 7-1 **REAR SUSPENSION DIAGNOSIS**

Problem	Symptoms	Possible Causes
Low riding height	Harsh ride quality, worn strikeout bumpers	Weak springs, worn control arm bushings, bent trailing arms or control arms
Steering pull	Steering pulls to the right or left when driving straight ahead	Improper rear wheel toe
Rear tire wear	Excessive rear tire tread wear	Improper rear wheel toe or camber
Rear chassis vibration	Rear chassis vibration when driving at a certain speed	Improper rear wheel, rotor, or drum balance; improper drive shaft balance or angles on rear-wheel-drive vehicles
Rear suspension noise	Rattling or squeaking noise when driving on road irregularities	Worn or dry stabilizer bar links and bushings, worn shock absorber or strut rod bushings, broken tubular rod in the rear axle inverted U-channel
Excessive rear suspension vertical oscillations	Excessive rear suspension bouncing when driving or road irregularities	Worn out shock absorbers or struts
Excessive rear chassis waddle	Excessive rear chassis lateral oscillations	Worn track bar bushings, loose track bar or brace

Terms to Know

Body sway
Brake torque test
Downshift test
Electronic vibration analyzer (EVA)
Lateral chassis movement
Neutral coast-down test
Neutral run-up test
Slow acceleration test
Spring silencers
Standing acceleration test
Steering input test
Suspension adjustment link
Wear indicators

CASE STUDY

A customer complained about steering pull to the left on a Chevrolet Impala. The customer also said the problem had just occurred in the last few days. The technician road tested the car and found the customer's description of the complaint to be accurate. A careful inspection of the tires indicated there was no abnormal tire wear on the front or rear tires. The vehicle was inspected for recent collision damage, but there was no evidence of this type of damage. After lifting the vehicle on a hoist, the technician checked all the front suspension components, including ball joints, control arms, control arm bushings, and wheel bearings. However, none of these front suspension components indicated any sign of wear or looseness.

Realizing that improper rear wheel tracking causes steering pull, the technician inspected the rear suspension. A pry bar was used to apply downward and rearward force to the trailing arms on the rear suspension. When this action was taken on the right rear trailing arm, the technician discovered the trailing arm bushing was very loose. This defect had allowed the right side of the rear axle to move rearward a considerable amount, which explained why the steering pulled to the left.

After installing a new trailing arm bushing, the alignment was checked on all four wheels, and the wheel alignment was within specifications. A road test indicated no evidence of steering pull or other steering problems.

ASE-Style Review Questions

1. While discussing lateral movement of the rear chassis:

   Technician A says this problem may be caused by loose stabilizer bar bushings.

   Technician B says this problem may be caused by loose track bar bushings.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While discussing excessive rear body sway or roll when driving on road irregularities:

   Technician A says this problem may be caused by worn spring insulators.

   Technician B says this problem may be the result of sagged rear springs.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. While discussing rear suspension curb riding height:

   Technician A says reduced rear curb riding height causes harsh riding.

   Technician B says reduced rear curb riding height increases steering effort.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. While discussing curb riding height:

   Technician A says the curb riding height is measured at the same location on each vehicle.

   Technician B says the curb riding height has no effect on other alignment angles.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

5. While discussing spring removal on a MacPherson strut rear suspension:

   Technician A says all the spring tension must be removed from the upper mount before the upper strut nut is loosened.

   Technician B says a vinyl-coated spring should be taped in the compressing tool contact area.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

6. The most likely cause of excessive rear chassis lateral movement is (are):

   A. A weak stabilizer bar.
   B. Worn track bar bushings.
   C. Worn-out struts.
   D. Sagged rear coil springs.

7. All these statements about rear suspension systems with lower control arms and ball joints are true EXCEPT:

   A. Worn lower control arm bushings do not affect tire tread wear.
   B. Some rear suspension ball joints have wear indicators.
   C. On some rear suspensions, the ball joint is pressed into the lower control arm.
   D. On some vehicles, the vehicle weight must be resting on the tires when the inner, lower control arm bolts are tightened.

8. Rear suspension adjustment links:

   A. May be lengthened or shortened to adjust rear wheel camber.
   B. Are connected from the lower control arm to the knuckle.
   C. May be loosened on each end with a wedge-type tool.
   D. Prevent fore-and-aft control arm and wheel movement.

9. On a rear suspension system with longitudinally mounted leaf springs:

   A. Improper vehicle tracking may be caused by a broken spring center bolt.
   B. Worn spring silencers may cause reduced curb riding height.
   C. A shackle is mounted between the front of the spring and the chassis.
   D. Longitudinal rear leaf springs are usually installed on independent rear suspension systems.

10. While diagnosing improper rear wheel tracking:

    A. Improper rear wheel tracking may be caused when both rear springs are sagged the same amount.
    B. A bent rear suspension tie-rod does not affect rear wheel tracking.
    C. Improper rear wheel tracking may result in steering pull when driving straight ahead.
    D. Improper rear wheel tracking may cause front wheel shimmy.

ASE Challenge Questions

1. A squeak in the rear suspension could be caused by all of the following EXCEPT:
   A. The suspension bushing.
   B. Weak spring leaves.
   C. Worn spring antifriction pads.
   D. A defective shock absorber.

2. A vehicle with a live-axle coil spring rear suspension has become hard to steer with harsh ride quality. Which of the following could be the cause of this problem?
   A. Worn lateral link bushings.
   B. Weak rear coil springs.
   C. Bent rear shock rod.
   D. Worn stabilizer bar bushings.

3. A customer says his 1993 Isuzu Trooper has become "real antsy" on a curve. An initial check of the rear suspension by pushing sideways against the bumper with the truck on the floor indicates wear.

   Technician A says worn sway bar bushings could be the problem.

   Technician B says a worn shock mount could be the problem.

   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. A car with independent rear suspension has excessive rear tire wear. An inspection of the rear tires shows they are worn on the inside edge and the tread is feathered.

   Technician A says the problem could be the tires are toeing out during acceleration.

   Technician B says worn control arm bushings could be the cause of the problem.

   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

5. The steering on a front-wheel-drive car pulls to the right.

   Technician A says the strut on the right rear suspension assembly could be the problem.

   Technician B says worn bushings of the left rear lower arm assembly could be the problem.

   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

Name ______________________________ Date ____________________

Remove and Service Rear Suspension Strut and Coil Spring Assembly

Upon completion of this job sheet, you should be able to remove and service rear suspension strut and coil spring assemblies.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Tasks C-10: Remove inspect, and install strut cartridge or assembly, strut coil spring, insulators (silencers), and upper strut bearing mount.

Tools and Materials

Floor jack
Safety stands
Hoist
Coil spring compressing tool

Describe the Vehicle Being Worked On:

Year __________ Make ________________ Model ______________________
VIN ________________________ Engine type and size ________________

Procedure

Task Completed

1. Remove the rear seat and the package trim tray. ☐
2. Remove the wheel cover, and loosen the wheel nuts. ☐
3. Lift the vehicle with a floor jack, and lower the chassis onto safety stands so the rear suspension is allowed to drop downward.
   Is the rear suspension properly supported on the safety stands? ☐ Yes ☐ No
   Instructor check ______________________________
4. Place the floor jack lift pad under the rear spindle on the side where the strut and spring removal is taking place. Raise the floor jack to support some of the suspension system weight.
   Is the floor jack placed under the rear spindle and supporting some of the vehicle weight? ☐ Yes ☐ No
   Instructor check ______________________________
5. Remove the rear wheel, disconnect the nut from the small spring in the lower arm, and remove the brake hose and antilock brake system (ABS) wire from the strut. ☐
6. Remove the stabilizer bar link from the strut, and loosen the strut-to-spindle mounting bolts. ☐
7. Remove the three upper support nuts under the package tray trim, and lower the floor jack to remove the strut from the knuckle. Remove the strut from the chassis. ☐
8. Following the vehicle and equipment manufacturers' recommended procedures, install a spring compressor on the coil spring, and tighten the spring compressor until all the spring tension is removed from the upper support.

Task Completed

Is the spring compressor properly installed on the coil spring? ☐ Yes ☐ No

Is the spring compressor tightened so all tension is removed from the upper support?

Instructor check ______________________________

☐ **9.** Install a bolt in the upper strut-to-spindle bolt hole and tighten the two nuts on the end of this bolt. One nut must be on each side of the strut bracket.

Clamp this bolt in a vise to hold the strut, coil spring, and spring compressor.

10. Using the special tool to hold the spring and strut from turning, loosen the nut from the strut rod nut.

Is all the coil spring tension removed from the upper strut mount by the spring compressor? ☐ Yes ☐ No

Is the strut rod nut loosened? ☐ Yes ☐ No

Instructor check ______________________________

☐ **11.** Remove the strut rod nut, upper support, and upper insulator.

☐ **12.** Remove the strut from the lower end of the spring.

☐ **13.** If the spring is to be replaced, rotate the compressor bolt until all the spring tension is removed from the compressing tool, then remove the spring from the tool.

14. Inspect the lower insulator and spring seat on the strut. If the spring seat is warped or damaged, replace the strut. A new cartridge may be installed in some rear struts.

Lower insulator condition: ☐ Satisfactory ☐ Unsatisfactory

Spring seat condition: ☐ Satisfactory ☐ Unsatisfactory

Strut condition: ☐ Satisfactory ☐ Unsatisfactory

List all the components that require replacement and explain the reasons for your diagnosis.

____

____

SERVICE TIP: If the plastic coating on a coil spring is chipped, the spring may break prematurely. The spring may be taped in the compressing tool contact areas to prevent chipping.

15. Visually inspect the coil spring, upper mount, insulator, and spring bumper. If any of these components are damaged, worn, or distorted, replacement is necessary.

Coil spring condition: ☐ Satisfactory ☐ Unsatisfactory

Upper mount condition: ☐ Satisfactory ☐ Unsatisfactory

Insulator condition: ☐ Satisfactory ☐ Unsatisfactory

Spring bumper condition: ☐ Satisfactory ☐ Unsatisfactory

List all the components that require replacement and explain the reasons for your diagnosis.

____

Instructor's Response ______________________________

____

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Name ______________________________ Date ____________________

Remove Rear Suspension Lower Control Arm and Ball Joint Assembly

Upon completion of this job sheet, you should be able to remove rear suspension lower control arm and ball joint assemblies.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Tasks C-3, C-5: Remove inspect, and install upper and lower control arms, bushings, shafts, and rebound bumpers. Remove, inspect, and install upper and/or lower ball joints.

Tools and Materials

Floor jack	Control arm removing tool
Safety stands	Transmission jack
Hoist	Ball joint removal and replacement tools

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ____________________________

VIN ______________________________ Engine type and size _______________________

Procedure | Task Completed

1. Lift the vehicle on a hoist with the chassis supported in the hoist and control arms dropped downward. The vehicle may be lifted with a floor jack and the chassis supported on safety stands. ☐
2. Remove the tire-and-wheel assembly. ☐
3. Remove the stabilizer bar from the knuckle bracket. ☐
4. Remove the parking brake cable retaining clip from the lower control arm. ☐
5. If the car has electronic level control (ELC), disconnect the height sensor link from the control arm. ☐
6. Install a special tool to support the lower control arm in the bushing areas. ☐
7. Place a transmission jack under the special tool and raise the jack enough to remove the tension from the control arm bushing retaining bolts. If the car was lifted with a floor jack and supported on safety stands, place a floor jack under the special tool.
   Is the special control arm support tool properly installed and supported?
   ☐ Yes ☐ No
   Instructor check ____
8. Place a safety chain through the coil spring and around the lower control arm.
   Is the safety chain properly installed? ☐ Yes ☐ No
   Instructor check ____
9. Remove the bolt from the rear control arm bushing. ☐

Task Completed

☐ **10.** Be sure the jack is raised enough to relieve the tension on the front bolt in the lower control arm and remove this bolt.

☐ **11.** Lower the jack slowly and allow the control arm to pivot downward. When all the tension is released from the coil spring, remove the safety chain, coil spring, and insulators.

12. Inspect the coil spring for distortion and proper free length. If the spring has a vinyl coating, check this coating for scratches or nicks. Check the spring insulators for cracks and wear.
Coil spring condition:: ☐ Satisfactory ☐ Unsatisfactory
List all the components that require replacement and explain the reasons for your diagnosis.
____
____
____

☐ **13.** Remove the nut on the inner end of the suspension adjustment link and disconnect this link from the lower control arm.

14. Remove the cotter pin from the ball joint nut, and loosen, but do not remove, the nut from the ball joint stud.
Is the ball joint nut loosened? ☐ Yes ☐ No
Instructor check ______________________________

☐ **15.** Use a special ball joint removal tool to loosen the ball joint in the knuckle.

☐ **16.** Remove the ball joint nut and the control arm.

17. Inspect the lower control arm for bends, distortion, and worn bushings.
Lower control arm condition: ☐ Satisfactory ☐ Unsatisfactory
List the control arm and related parts that require replacement and explain the reasons for your diagnosis.
____
____
Instructor check ______________________________

☐ **18.** Use a special ball joint pressing tool to press the ball joint from the lower control arm.

☐ **19.** Use the same pressing tool with different adapters to press the new ball joint into the control arm.

Instructor's Response ______________________________
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Name ______________________________ Date ____________________

Install Rear Suspension Lower Control Arm and Ball Joint Assembly

Upon completion of this job sheet, you should be able to install rear suspension lower control arm and ball joint assemblies.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task C-3, C-5: Remove, inspect, and install upper and lower control arms, bushings, shafts, and rebound bumpers. Remove, inspect, and install upper and/or lower ball joints.

Tools and Materials

Floor jack
Safety stands
Hoist
Control arm removing tool
Transmission jack

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ____________________________

VIN ______________________________ Engine type and size ________________________

Procedure

Task Completed

1. Install the ball joint stud in the knuckle and install the nut on the ball joint stud. Tighten the ball joint nut to the specified torque, and then tighten the nut an additional 2/3 turn. If necessary, tighten the nut slightly to align the nut castellations with the cotter pin hole in the ball joint stud, and install the cotter pin.
   Specified ball joint stud nut torque ______________________________
   Actual ball joint stud nut torque ______________________________
2. Snap the upper insulator on the coil spring. Install the lower spring insulator and the spring in the lower control arm.
   Is the coil spring and insulator properly installed in lower control arm?
   ☐ Yes ☐ No
   Instructor check ______________________________
3. Be sure the top of the coil spring is properly positioned in relation to the front of the vehicle.
   Is the top of the spring properly positioned? ☐ Yes ☐ No
   Instructor check ______________________________
4. Install the special tool on the inner ends of the control arm, and place the transmission jack or floor jack under the special tool. ☐
   Is the special tool properly supported on the control arm? ☐ Yes ☐ No
   Instructor check ______________________________
   Is the special tool properly supported on the transmission or floor jack?
   Instructor check ______________________________

Task Completed

☐ 5. Slowly raise the transmission jack until the control arm bushing openings are aligned with the openings in the chassis.

6. Install the bolts and nuts in the inner ends of the control arm. Do not torque these bolts and nuts at this time.

7. Install the stabilizer-bar-to-knuckle bracket fasteners to the specified torque.
Specified torque on stabilizer-bar-to-knuckle bracket fasteners ____________
Actual torque on stabilizer-bar-to-knuckle bracket fasteners ____________

☐ 8. Install the parking brake retaining clip.

☐ 9. If the vehicle has ELC, install the height sensor link, and tighten the fastener to the specified torque.

10. Install the suspension adjustment link and tighten the fastener to the specified torque. Install cotter pins as required.
Specified adjustment link retaining nut torque ____________
Actual adjustment link retaining nut torque ____________
Are the cotter pins properly installed in adjustment link retaining nuts?
☐ Yes ☐ No
Instructor check ____________

☐ 11. Remove the transmission jack or floor jack, and install the tire-and-wheel assembly.

12. Lower the vehicle onto the floor. Tighten the wheel hub nuts and lower control arm bolts and nuts to the specified torque.
Specified wheel nut torque ____________
Actual wheel nut torque ____________
Specified control arm retaining nut torque ____________
Actual control arm retaining nut torque ____________

CAUTION: The pivot bolts and nuts in the inner ends of the lower control arm must be tightened to the specified torque with the vehicle supported on the wheels and the suspension at normal curb height. Failure to follow this procedure may adversely affect ride quality and steering characteristics.

Instructor's Response ____________
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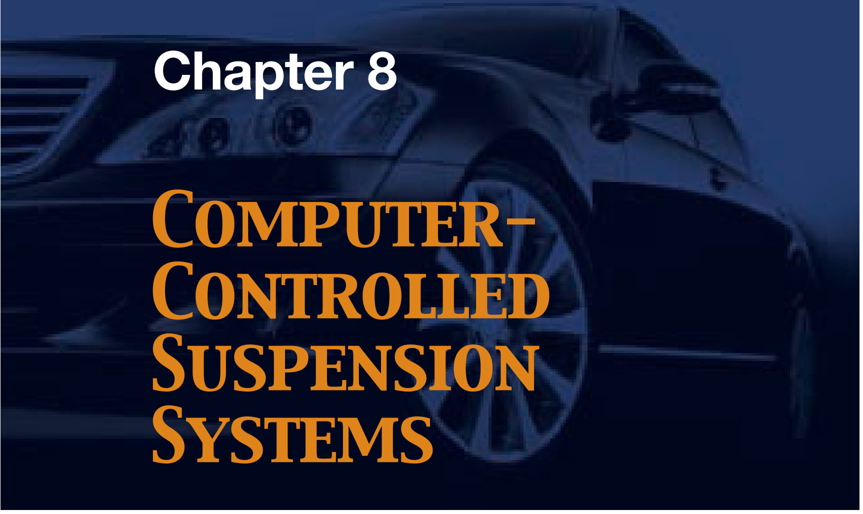

Chapter 8

Computer-Controlled Suspension Systems

Upon completion and review of this chapter, you should be able to understand and describe:

- The conditions that cause a programmed ride control (PRC) system to switch from the normal to the firm mode.
- How the firm ride condition is obtained in PRC struts.
- The major components in an electronic air suspension system.
- How air is forced into and exhausted from the air springs in an air suspension system.
- How an electronic air suspension system corrects low suspension trim height.
- The operation of an electronic air suspension system while driving the car with the doors closed and the brake pedal applied.
- The normal operation of the warning lamp in an electronic air suspension system.
- The three modes in the air suspension system on some modern four-wheel-drive sport utility vehicles (SUVs).
- How unnecessary rear suspension height corrections are prevented on irregular road surfaces with an air suspension system.
- The design of the struts and air springs in an automatic air suspension system.
- The design of an electronic rotary height sensor.
- Speed-leveling capabilities and the advantage of this function in a suspension control module.
- The operation of an automatic ride control (ARC) system in relation to transfer case modes.
- The inputs in an electronic suspension control (ESC) system.
- The advantages of an ESC system with magneto-rheological fluid in the shock absorbers compared to other computer-controlled suspension systems.
- The operation of the rear electronic level control system that is combined with the road sensing suspension system.
- The operation of the speed sensitive steering system that is combined with the road sensing suspension system.
- The operation of a stability control system.
- The advantages of a traction control system.
- Various vehicle network systems.
- Active cruise control, lane departure warning, and collision-mitigation systems.

Introduction

We are all aware of the ever accelerating electronics revolution in the 1990s and early 2000s. Most industries have felt the impact of this revolution, and the automotive industry is no exception. Computers have greatly influenced the way vehicles are designed and built. Most systems on the automobile, including the suspension system, have been impacted by the computer. Many drivers like a soft, comfortable ride while driving normally on the highway. However, many of these same drivers prefer a firm ride during hard cornering, severe braking, or fast acceleration. A firm ride under these driving conditions reduces body sway and front end dive or lift. Prior to the age of electronics, cars were designed to provide either a soft, comfortable ride or a firm ride. Drivers who wanted a firm ride selected a sports car with a suspension designed to supply the type of ride and handling characteristics they desired. Car buyers who wanted a softer ride purchased a family sedan with a suspension designed to provide a softer, more comfortable ride.

Thanks to computer control, suspension system manufacturers can now provide a soft ride during normal highway driving, and then almost instantly switch to a firm ride during hard cornering, braking, fast acceleration, and high-speed driving. The computer-controlled suspension system allows the same car to meet the demands of both the driver who desires a soft ride, and the driver who wants a firm ride. Because computer-controlled suspension systems reduce body sway during hard cornering, these systems provide improved steering control.

Some computer-controlled suspension systems also supply a constant vehicle riding height regardless of the vehicle passenger or cargo load. This action maintains the vehicle's cosmetic appearance as the passenger and/or cargo load is changed. Maintaining a constant riding height also supplies more constant suspension alignment angles, which may provide improved steering control.

A Bit of History

Suspension systems evolved slowly for many years. In the 1940s, many front suspensions were changed from I-beam to short-and-long arm. MacPherson strut suspensions replaced the short-and-long arm suspension systems on front-wheel-drive cars introduced in the late 1970s and 1980s. In the 2000s, we are experiencing an ever expanding use of electronics technology in automotive suspension systems. Some computer-controlled suspension systems now have the capability to react to road or driving conditions in one millisecond to improve ride and handling quality. The use of electronics technology will continue to improve suspension systems so they provide better handling characteristics and safety with longer tire life.

Programmed Ride Control System

System Design

The **programmed ride control (PRC) system** is available on some Ford cars. Some import cars have a similar system. The damping action of the front and rear struts and shocks is automatically controlled by the PRC system to provide improved ride and handling characteristics under various driving conditions. The main components in the PRC system are (Figure 8-1):

1. Steering sensor
2. Brake sensor
3. Speed sensor
4. Struts and shocks with electric actuators
5. Control module
6. Electronic engine control IV (EEC IV) powertrain control module (PCM)
7. Firm and plush shock relays
8. Mode select switch
9. Mode indicator light

The **programmed ride control (PRC) system** adjusts shock absorber and strut damping.

Steering Sensor

The **steering sensor** is mounted on the steering column. This sensor contains a pair of **light-emitting diodes (LEDs)** and a matching pair of **photo diodes**. A slotted disc attached to the steering shaft rotates between the LEDs and photo diodes when the steering wheel is turned (Figure 8-2). This disc contains 20 slots spaced at 9° intervals. A signal is sent from the steering sensor to the control module in relation to the amount and speed of steering wheel rotation.

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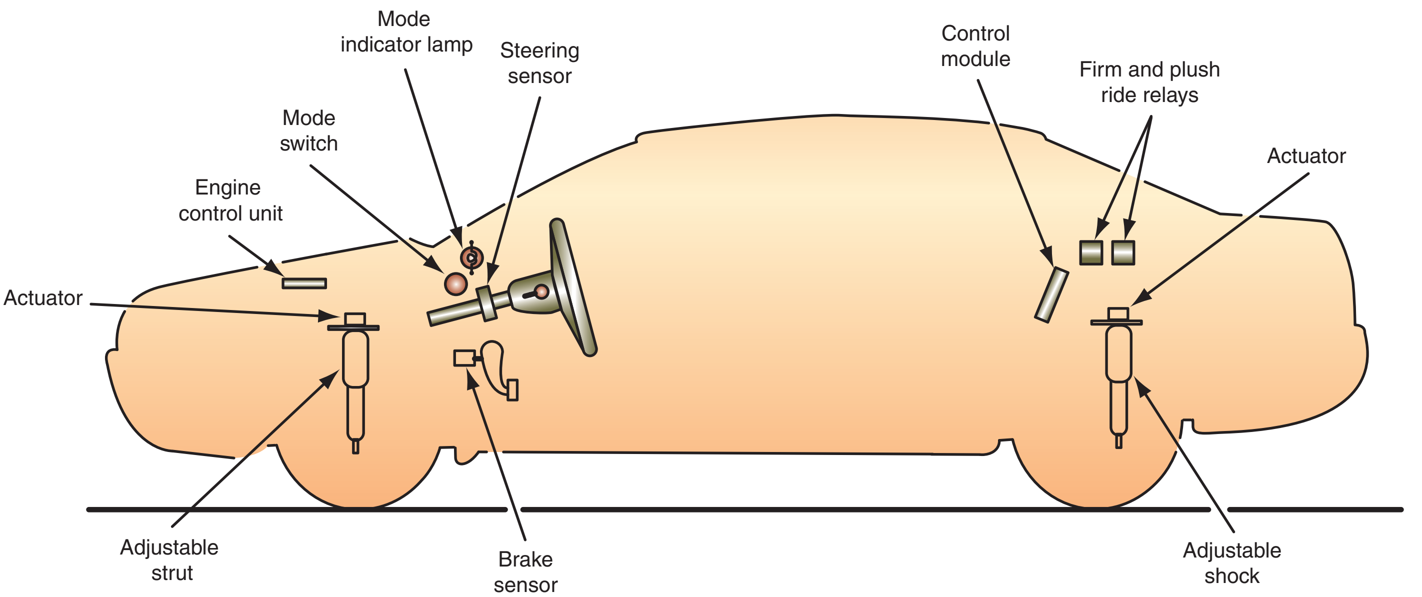

FIGURE 8-1 **Programmed ride control (PRC) system components.**

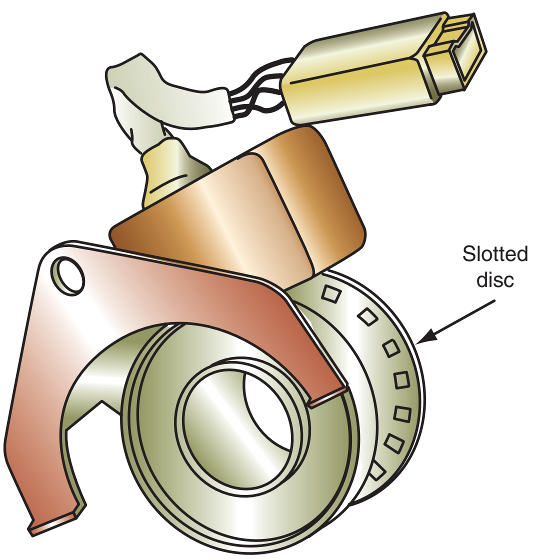

FIGURE 8-2 **Steering sensor.**

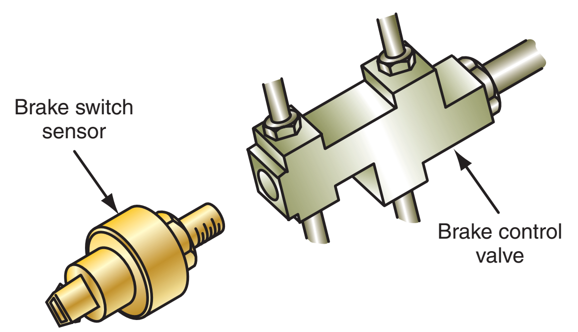

FIGURE 8-3 **Brake switch.**

The electronic engine control IV (EEC IV) or the electronic engine control V (EEC V) system refers to a computer system that controls many outputs, such as fuel injection and spark advance, on most Ford products.

Brake Sensor

The brake sensor is a normally open (NO) switch mounted in the brake control valve assembly (Figure 8-3). When the brake fluid pressure reaches 400 pounds per square inch (psi) or 2,758 kilopascals (kPa), the **brake pressure switch** closes and sends a signal to the control module.

Vehicle Speed Sensor

The vehicle speed sensor is usually mounted in the speedometer cable outlet of the transaxle or transmission (Figure 8-4). This sensor sends a vehicle speed signal to the control module. This signal is also used by the PCM in the EEC IV system.

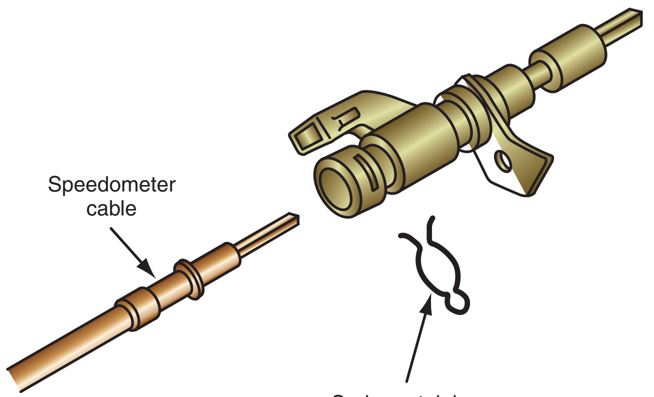

FIGURE 8-4 **Vehicle speed sensor.**

Strut and Shock Actuators

An **actuator** is positioned in the top of each strut and shock (Figure 8-5). Each actuator contains a single pole armature, a pair of permanent magnets, and a position switch. When current is applied through the plush relay to the armature, the magnetic fields of the armature and the permanent magnets repel each other (Figure 8-6). This action causes clockwise armature rotation until the armature hits the internal stop. Under this condition, the leaf-spring switch is open in the position sensor circuit and no signal is returned to the PRC control module.

An **actuator** in a strut or shock absorber varies damping action when activated and de-activated.

If current is applied through the firm relay to the armature, there is an attraction between the magnetic fields of the armature and permanent magnets. This attraction causes

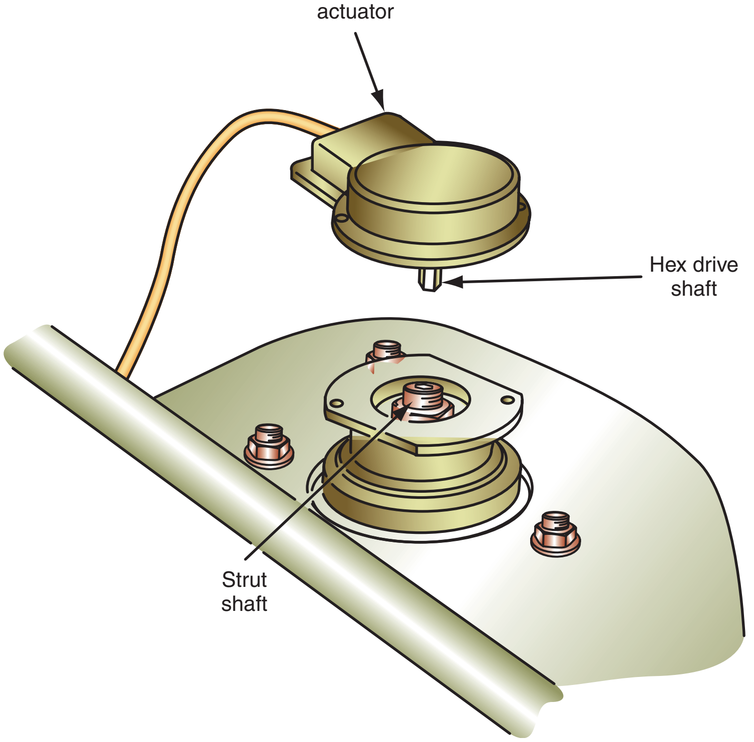

FIGURE 8-5 **Strut actuator.**

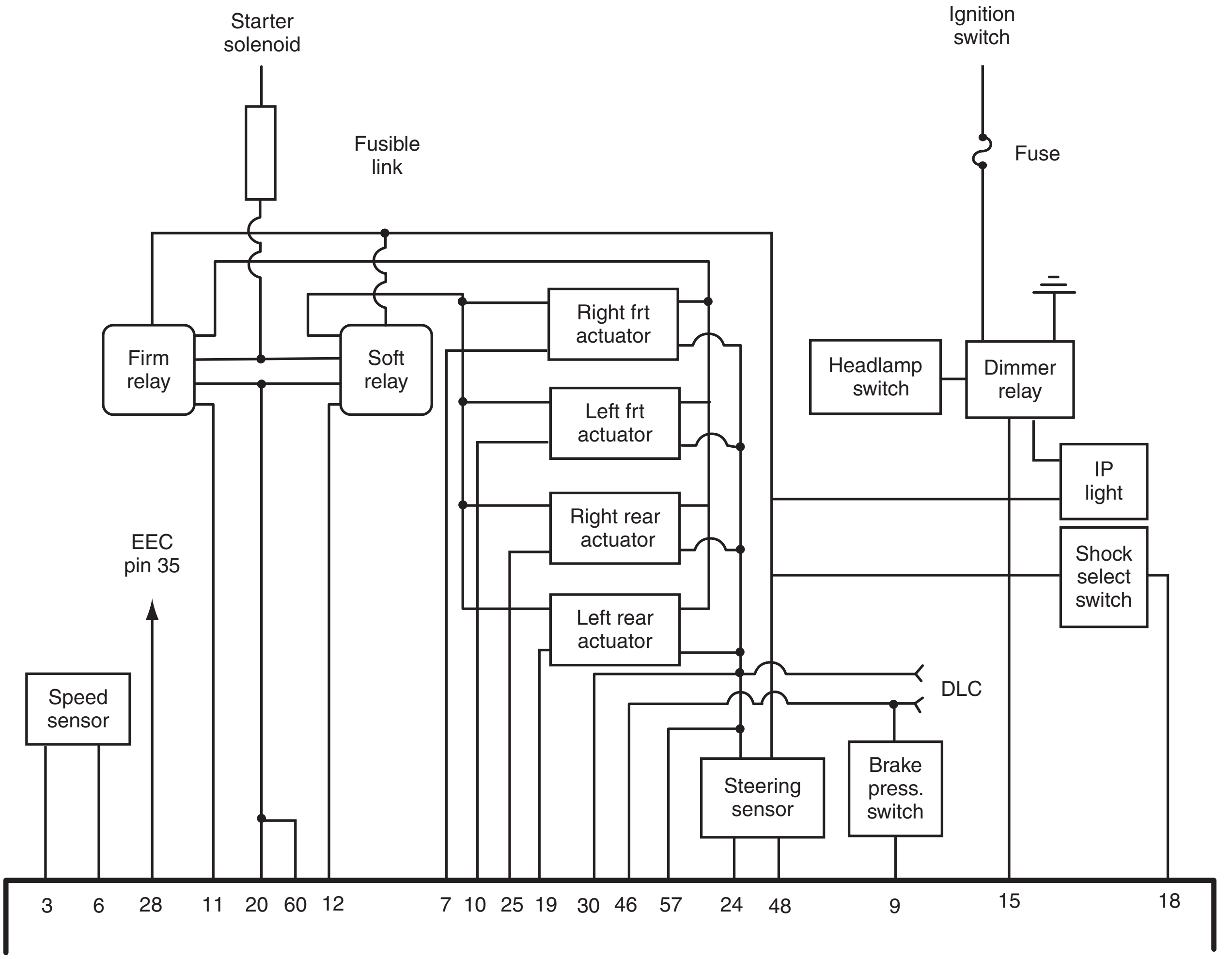

FIGURE 8-6 **Firm relay, strut actuators, and other PRC system components.**

counterclockwise armature rotation until the armature contacts the internal stop. The armature rotates an internal strut or shock valve to restrict oil movement and provide increased suspension damping. In the firm position, the leaf-spring switch closes and sends a feedback signal to the control module. The armature movement is 60° and armature response time is 30 milliseconds (ms).

Operation

The **firm relay** energizes the strut actuators in the firm mode.

The **soft relay** supplies voltage to the strut actuators in the soft mode.

When the mode select switch is in the Auto position, the **firm relay** is de-energized and the **soft relay** is energized. Under this condition, current flows through the plush ride relay and the shock/strut actuators. This current is then routed to ground through the firm ride relay. If the vehicle is driven under normal speed and relatively straight-ahead conditions, this mode remains in operation.

The following conditions cause the PRC system to switch from the auto mode to the firm mode:

1. Vehicle speed above 83 miles per hour (mph) or 133 kilometers per hour (km/h)
2. Engine acceleration at 90 percent throttle opening or 8 psi (55 kPa) turbo boost pressure
3. Lateral vehicle acceleration above 0.35 g
4. Brake pressure of 400 psi (2,758 kPa) or more

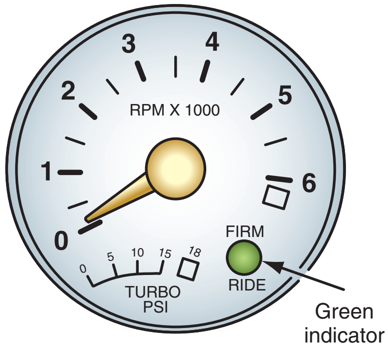

FIGURE 8-7 **Mode indicator light.**

The vehicle acceleration signal is sent from the **throttle position sensor (TPS)** to the powertrain control module (PCM) in the EEC IV system. This signal is relayed to the PRC control module. Lateral vehicle acceleration is sensed by the steering sensor.

When the PRC control module receives an input signal that requires firm ride control, the control module energizes the firm relay and de-energizes the soft relay. This action results in current flow from the firm ride relay through the shock/strut actuators, and the soft ride relay to ground. Therefore, shock/strut actuator current is reversed and the armature in each actuator moves the shock/strut valves to the Firm position.

The mode indicator light in the tachometer glows when the PRC system is in the Firm mode (Figure 8-7). During the first 80 seconds after the ignition switch is turned on, the PRC system does not respond to changes in vehicle direction. This action allows the PRC control module to calculate the straight-ahead position.

If the mode select switch is placed in the Firm position, the system remains in the firm mode continually. In this mode, the mode indicator light remains on. In the firm mode, the shocks/struts provide approximately three times the damping action on the extension stroke compared to the normal mode.

The **throttle position sensor (TPS)** is usually a potentiometer connected to the throttle shaft. When the throttle is opened, a movable contact slides around a rotary variable resistor, and this contact movement changes the sensor voltage signal in relation to throttle opening. The TPS signal informs the PCM in the EECV system regarding the amount of throttle opening.

Air springs support the chassis weight in an air suspension system.

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Electronic Air Suspension System Components

Air Springs

In an air suspension system, the **air springs** replace the coil springs in conventional suspension systems. These air springs have a composite rubber and plastic membrane that is clamped to a piston located in the lower end of the spring. An end cap is clamped to the top of the membrane and an air spring valve is positioned in the end cap. The air springs are inflated or deflated to provide a constant vehicle trim height. Front air springs are mounted between the control arms and the crossmember (Figure 8-8). The lower end of these air springs is retained in the control arm with a clip, and the upper end is positioned in a crossmember spring seat. The front shock absorbers are mounted separately from the air springs.

In some modern air suspension systems the air springs are mounted and sealed on the shock absorbers (Figure 8-9). The lower end of the shock absorber is attached to the lower control arm through an insulating bushing, and the upper end of the shock absorber is attached to the chassis through an insulating mount. This type of air suspension system has aluminum front lower control arms and spindles, and forged steel upper control arms. Ball joints are mounted in the outer ends of the upper and lower control arms. The aluminum suspension components reduce the unsprung weight and improve ride quality. Reducing vehicle weight also improves fuel economy. The upper and lower ball joints are an integral part of the control arms, and these ball joints cannot be replaced separately.

CAUTION:
The ball joint studs in the upper ball joints do not have a press fit in the steering knuckle. When loosening these ball joint nuts, a hex holding feature on the ball joint stud prevents the stud from rotating when loosening the ball joint nuts. If the upper ball joint stud rotates in the aluminum knuckle the knuckle opening may be damaged.

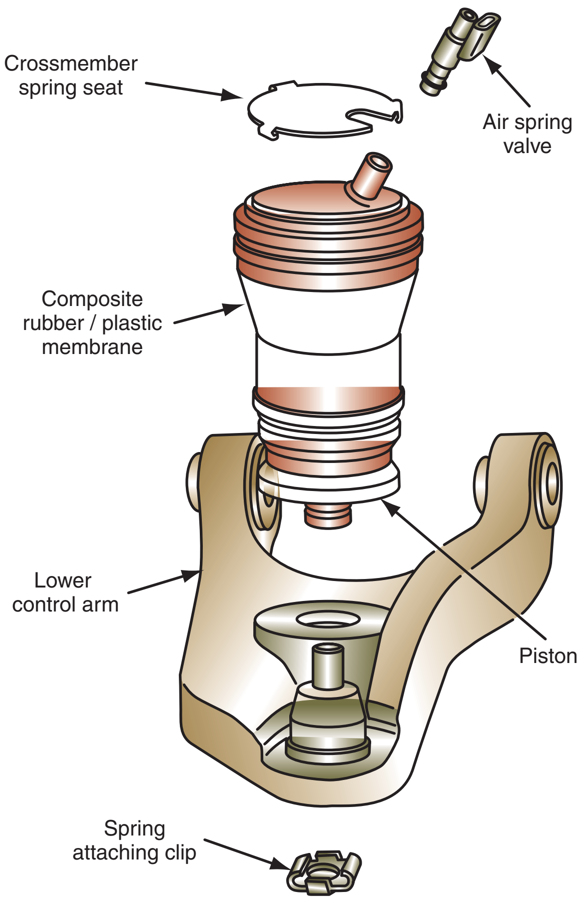

FIGURE 8-8 **Front air spring.**

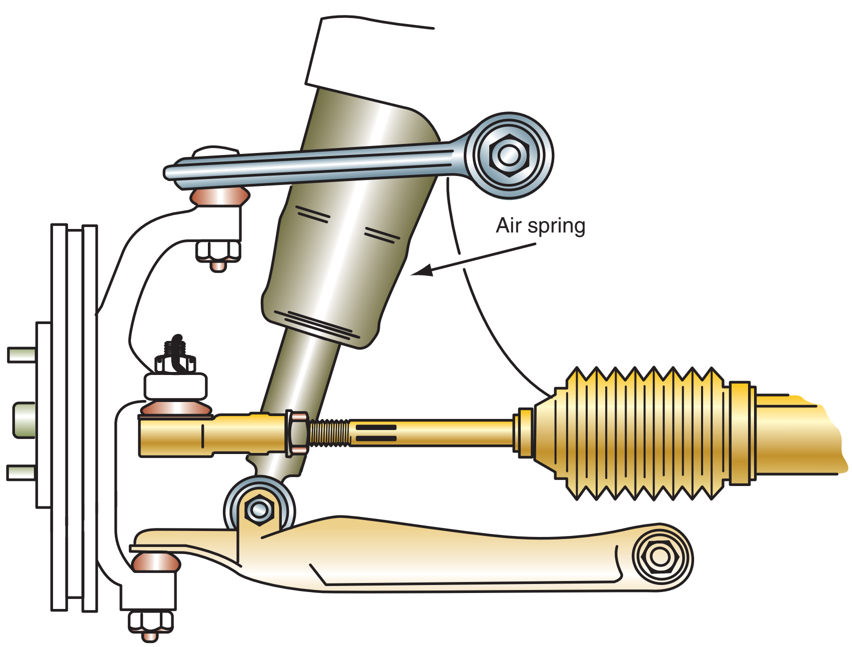

FIGURE 8-9 **Air spring mounted on the shock absorber.**

Other vehicles have the air springs mounted over the front and rear struts, and these struts contain a solenoid actuator that varies the strut valve opening to control ride firmness (Figures 8-10 and 8-11). These strut actuators are similar to the ones explained previously in this chapter on the PRC system. Some of these air suspension systems that control ride firmness are not driver adjustable. The suspension module controls the strut firmness automatically in relation to the module inputs. This type of system may be called an automatic air suspension system. Some vehicles with solenoid actuators in the struts have up to four suspension modes that may be selected by the driver. One premium luxury car has these driver selectable suspension modes:

1. Comfort—provides a smooth luxurious ride.
2. Automatic—the suspension computer provides the best possible combination of comfort and handling based on speed, driver style, and road conditions.
3. Dynamic—stiffest, lowest, sportiest, most aerodynamic suspension mode.
4. Life—for rougher roads, steep approaches, and deep snow. This mode is used only for low speed driving.

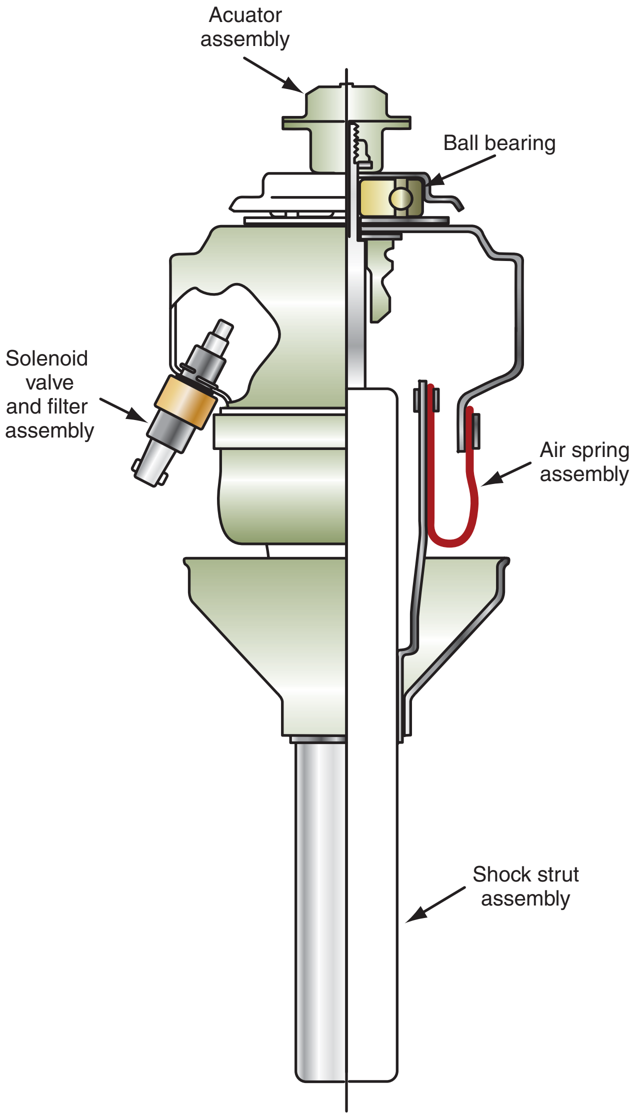

FIGURE 8-10 **Front air spring and strut assembly.**

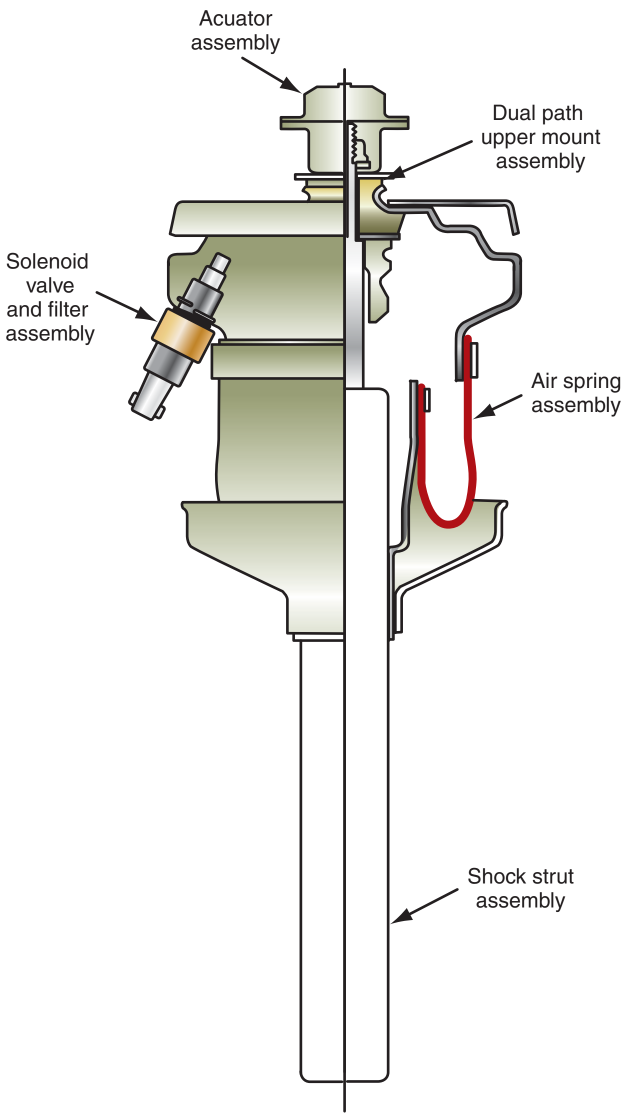

FIGURE 8-11 **Rear air spring and strut assembly.**

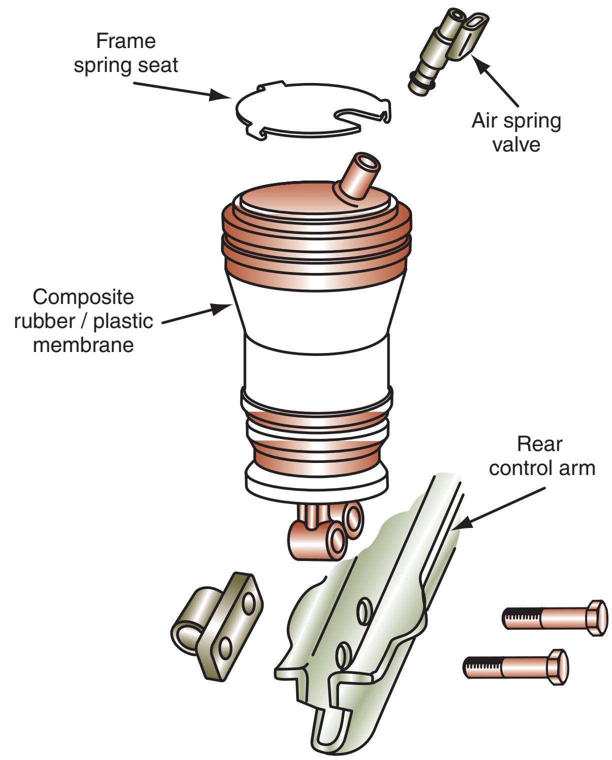

FIGURE 8-12 **Rear air spring mounting.**

When the driver selects a suspension mode, the suspension module positions the strut actuators to provide the desired ride quality, and this module also adjusts the air spring pressure to provide the appropriate ride height.

This type of air suspension system dramatically reduce body roll and pitch that occurs during cornering and hard braking. Because this air suspension system lowers the ride height at higher speeds, it improves aerodynamic efficiency.

Cross-axis ball joints contain large insulating bushings in place of typical ball joints.

The rear air springs are similar to the front air springs and also have similar mountings. Some rear air springs are mounted between the rear suspension arms and the frame with the shock absorbers mounted separately from the air springs (Figure 8-12). Other rear air springs are mounted over the rear shock absorbers, and the shock absorbers are mounted between the lower control arms and the frame. Some modern air suspension systems on four-wheel-drive vehicles have rear knuckles with **cross-axis ball joints**. The lower cross-axis ball joint is a round insulating bushing mounted in the lower control arm, and a bolt attaches this bushing to the lower end of the knuckle. The upper cross-axis ball joint is a round insulating bushing mounted in the top of the knuckle, and a bolt attaches this bushing to the upper control arm (Figure 8-13). In this rear suspension system the upper and lower control arms are made from aluminum. An adjustable toe link is connected from the knuckle to the frame to provide a rear toe adjustment. Rear wheel camber can be adjusted by installing a camber adjustment kit in place of the upper knuckle-to-control arm retaining bolt.

Air Spring Valves

An **air spring solenoid valve** allows air to flow into and out of an air spring.

An **air spring solenoid valve** is mounted in the top of each air spring (Figure 8-14). These valves are an electric solenoid-type valve that is normally closed. When the valve winding is energized, plunger movement opens the air passage to the air spring. Under this condition, air may enter or be exhausted from the air spring. Two O-ring seals are located on the end of the valves to seal them into the air spring cap. The valves are installed in the air spring cap with a two-stage rotating action similar to a radiator pressure cap.

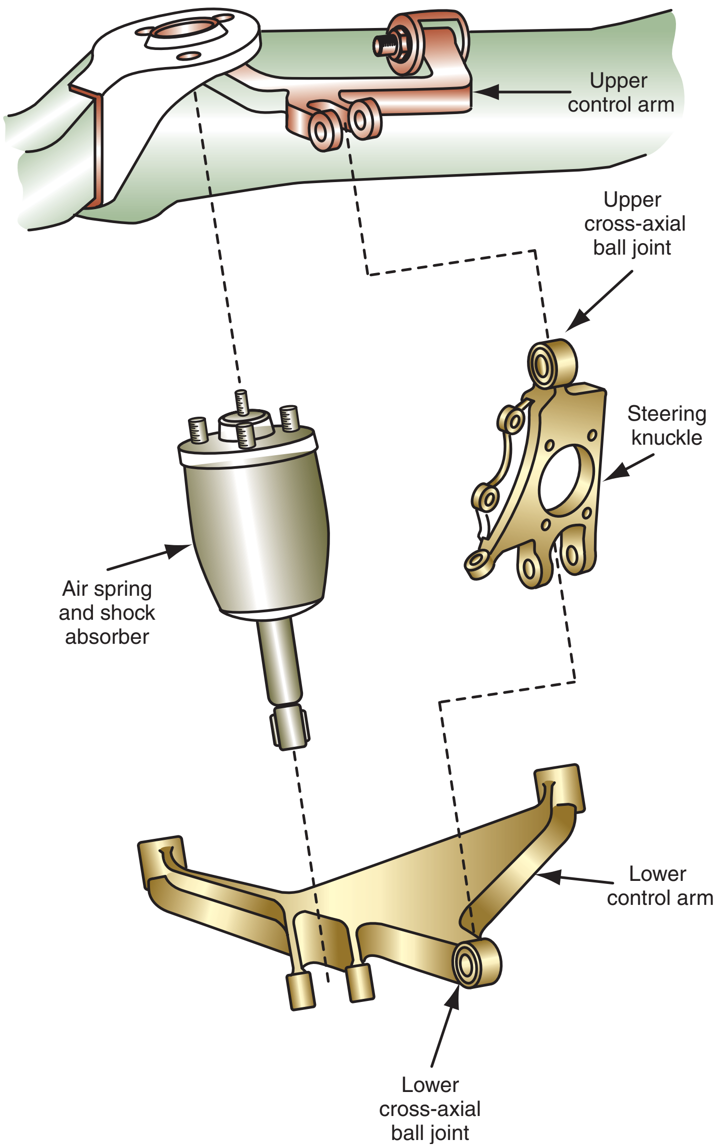

FIGURE 8-13 **Rear air suspension system with cross-axis ball joints and air spring mounted over the shock absorber.**

Air Compressor

A single piston in the air compressor is moved up and down in the cylinder by a crankshaft and connecting rod (Figure 8-15). The armature is connected to the crankshaft, and therefore the rotating action of the armature moves the piston up and down. Armature rotation occurs when 12 V are supplied to the compressor input terminal. Intake and discharge valves are located in the cylinder head. An air dryer that contains a silica gel is mounted on the compressor. This silica gel removes moisture from the air as it enters the system.

Nylon air lines are connected from the compressor outlets to the air spring valves. The compressor operates when it is necessary to force air into one or more air springs to restore the vehicle trim height.

An air **vent valve** is located in the compressor cylinder head (Figure 8-16). This normally closed electric solenoid valve allows air to be vented from the system. When it is necessary to exhaust air from an air spring, the air spring valve and vent valve must be energized at the same time with the compressor shut off. Air exhausting is necessary if the vehicle trim height is too high.

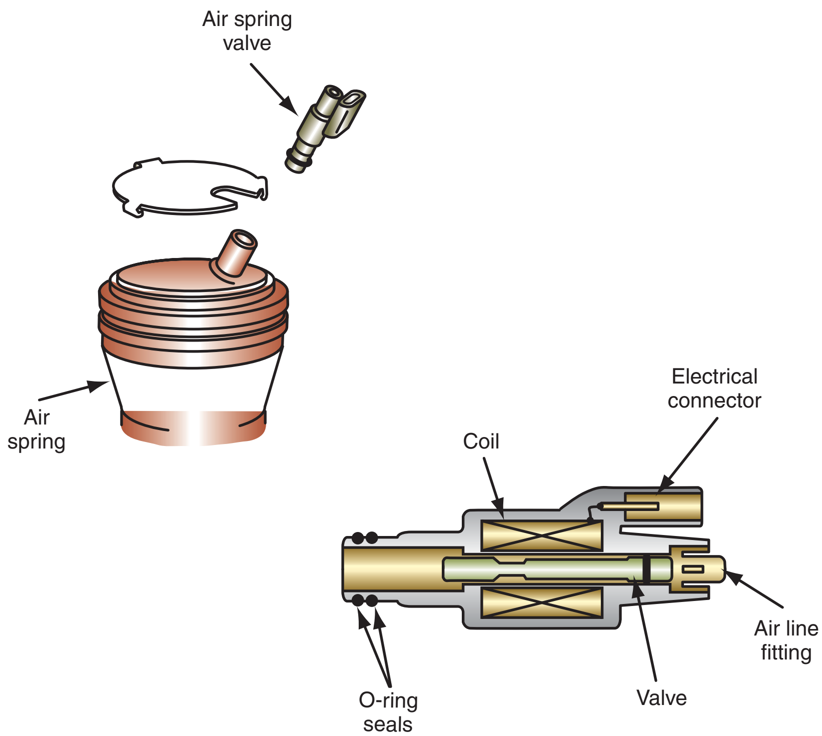

FIGURE 8-14 **Air spring valve.**

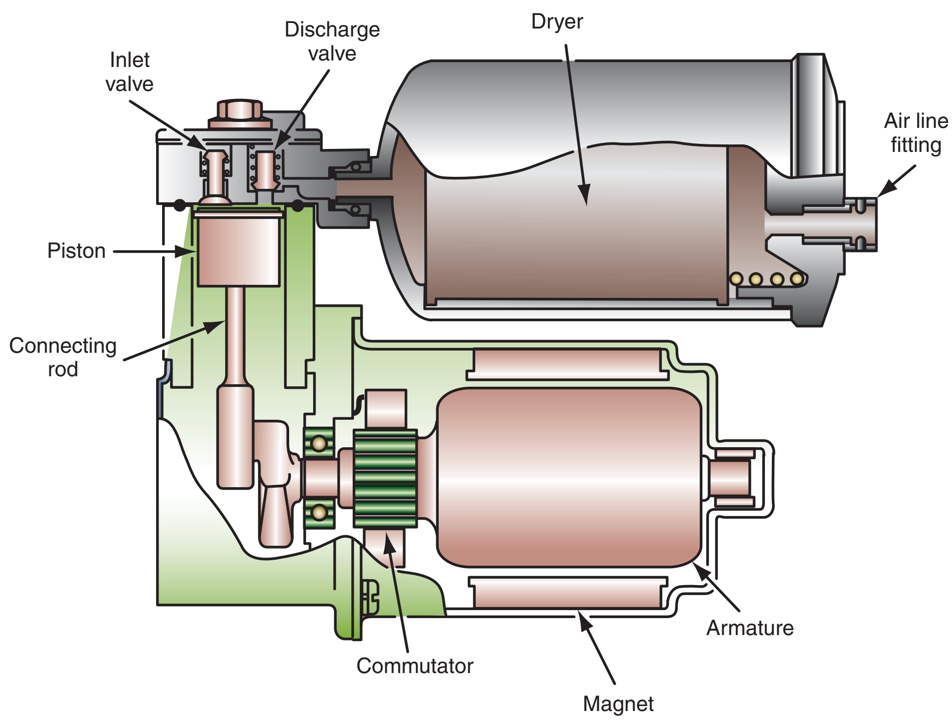

FIGURE 8-15 **Air compressor.**

Compressor Relay

When the compressor relay is energized, it supplies 12 V through the relay contacts to the compressor input terminal (Figure 8-17). The relay contacts open the circuit to the compressor if the relay is deenergized. An electronic relay is used in some air suspension systems.

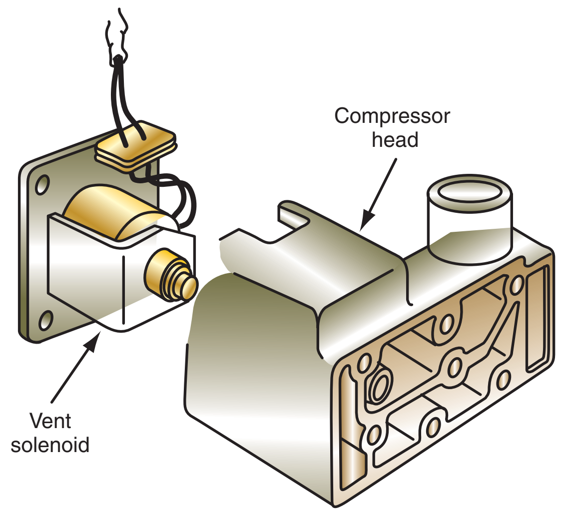

FIGURE 8-16 **Air vent valve.**

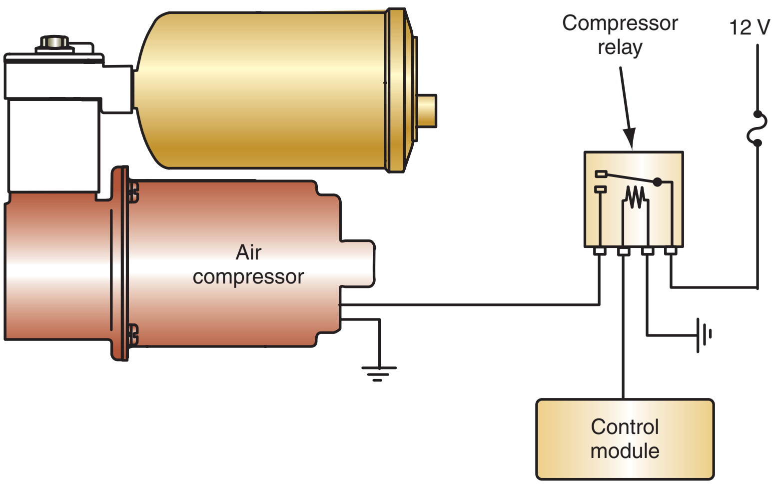

FIGURE 8-17 **Compressor relay.**

Control Module

The control module is a microprocessor that operates the compressor, vent valve, and air spring valves to control the amount of air in the air springs and maintain the trim height. The control module is located in the trunk (Figure 8-18) on some models. On other models the module is mounted under the instrument panel above the parking brake.

The control module turns on the suspension service indicator light in the roof panel or instrument panel to alert the driver when a suspension defect occurs. Diagnostic capabilities are designed into the suspension module. On some vehicles the suspension module is called a vehicle dynamics module (VDM). On many air suspension systems the suspension module is interconnected via data links to some of the other onboard computers and the data link connector (DLC) under the dash. A scan tool may be connected to the DLC to diagnose the air suspension and other electronic systems on the vehicle. The data links allow data transmission between the on-board computers and the DLC. For example, the vehicle speed sensor (VSS) signal may be sent through connecting wires to the powertrain control module (PCM) that controls engine functions. If the VSS signal is required by the suspension module, the PCM transmits the VSS signal through the data links. If an electronic defect occurs in a modern air suspension system, a diagnostic trouble code (DTC) is set in the suspension module memory. When a scan tool is connected to the DLC, the suspension module transmits the DTC through the data links to the DLC and scan tool.

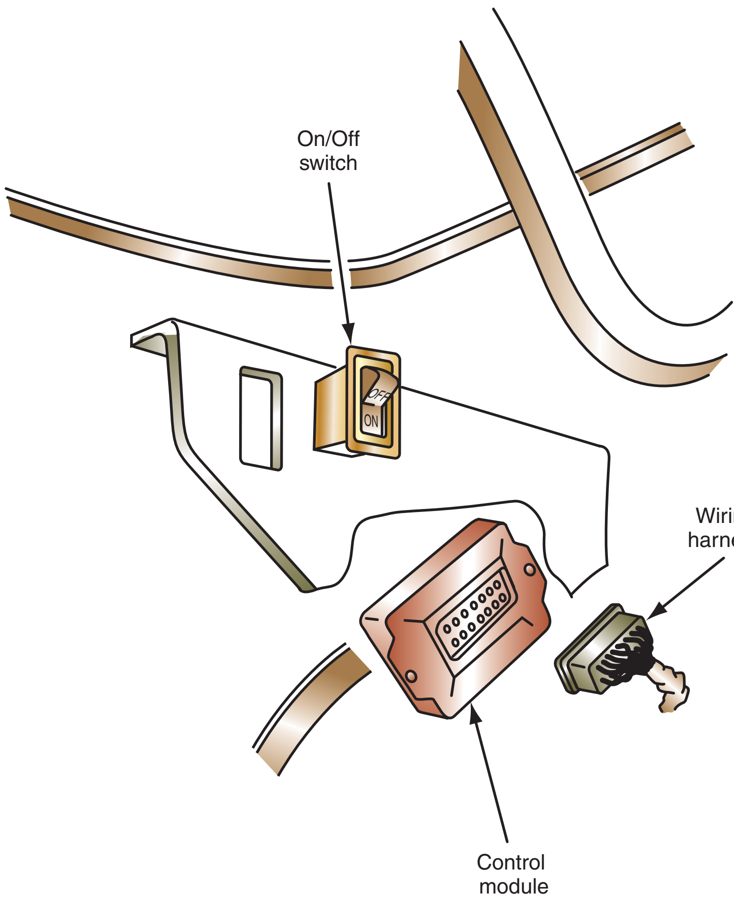

FIGURE 8-18 **Control module.**

On/Off Switch

The On/Off switch opens and closes the 12 V supply circuit to the suspension module. This switch is located in the trunk (Figure 8-19). Depending on the vehicle make and model year, one or two panels in the trunk may have to be removed to access the On/Off switch. The On/Off switch must be turned off before the vehicle is hoisted, jacked, or towed. Certain air suspension service procedures may require this switch to be placed in the Off position.

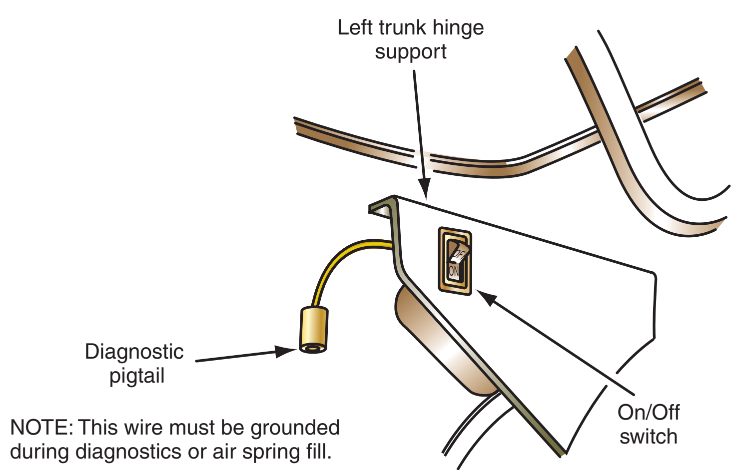

FIGURE 8-19 **On/Off switch.**

WARNING: If the vehicle is hoisted, jacked, or towed with the electronic air suspension switch in the On position, personal injury or vehicle damage may occur.

Height sensors send an electric signal to the control module in relation to curb riding height.

Height Sensors

In the air suspension system, there are two front **height sensors** located between the lower control arms and the crossmember. A single rear height sensor is positioned between the suspension arm and the frame (Figure 8-20). Each height sensor contains a magnet slide that is attached to the upper end of the sensor. This magnet slide moves up and down in the lower sensor housing as changes in vehicle trim height occur (Figure 8-21). The lower sensor housing contains two electronic switches that are connected through a wiring harness to the control module.

Trim height refers to the distance between the chassis and the road surface measured at a specific location recommended by the vehicle manufacturer.

When the vehicle is at **trim height,** the switches remain closed and the control module receives a trim height signal. If the magnet slide moves upward, the above trim switch opens and a **lower vehicle command** is sent from the height sensor to the module. When this signal is received by the module, it opens the appropriate air spring valve and the vent valve. This action exhausts air from the air spring and corrects the above trim height condition. Downward magnet slide movement closes the above trim switch and opens the below trim switch. If this action occurs, the height sensor sends a **raise vehicle command** to the module. When the control module receives this signal, it energizes the compressor relay and starts the compressor. The control module opens the appropriate air spring valve, and this action forces air into the air spring to correct the below trim height condition. The height sensors are serviced as a unit.

Electronic rotary height sensors have an internal rotating element and these sensors send voltage signals to the control module in relation to the curb riding height.

Some air suspension systems have **electronic rotary height sensors**. Each rotary height sensor contains a permanent magnet rotor and a **Hall element** (Figure 8-22). An arm on the height sensor is attached to the rotor. The height sensor body is mounted on the chassis and a linkage is connected from the sensor arm to the suspension (Figure 8-23). Suspension movement rotates the permanent magnet rotor and changes the voltage signal in the Hall

A **Hall element** is an electronic device that produces a voltage signal when the magnetic field approaches or moves away from the element.

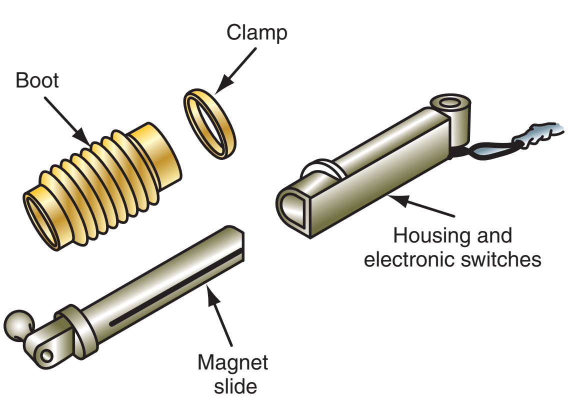

FIGURE 8-20 **Height sensor.**

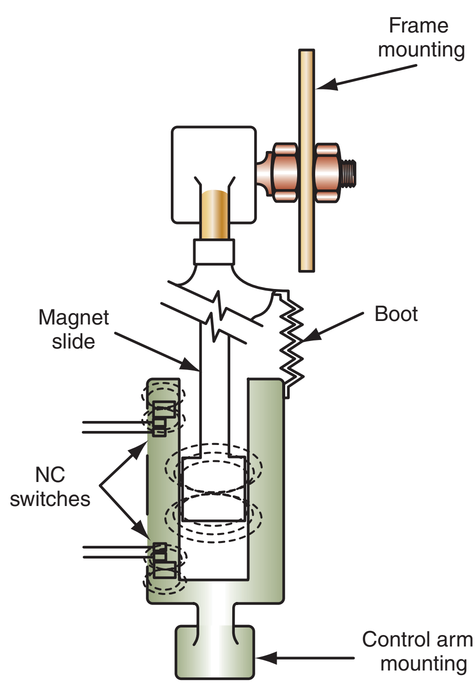

FIGURE 8-21 **Rear height sensor mounting.**

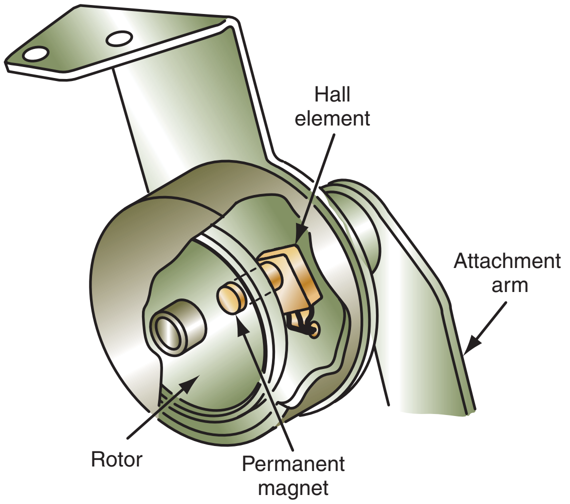

FIGURE 8-22 **Electronic rotary height sensor.**

FIGURE 8-23 **Height sensor mounting.**

CAUTION:
Never attempt to probe the electronic switches in slide-type height sensors. This action may damage the sensor.

element. The voltage signal from a rotary height sensor is proportional to trim height, above trim height, and below trim height.

Warning Lamp

When the control module senses a system defect, the module turns on the air suspension warning lamp in the roof console or instrument panel to inform the driver that a problem exists (Figure 8-24). If the air suspension system is working normally, the warning lamp will be on for one second when the ignition switch is turned from the Off to the Run position. After this time, the warning lamp should remain off. This lamp does not operate with the ignition switch in the start position. The warning lamp is used during the self-diagnostic procedure and the spring fill sequence.

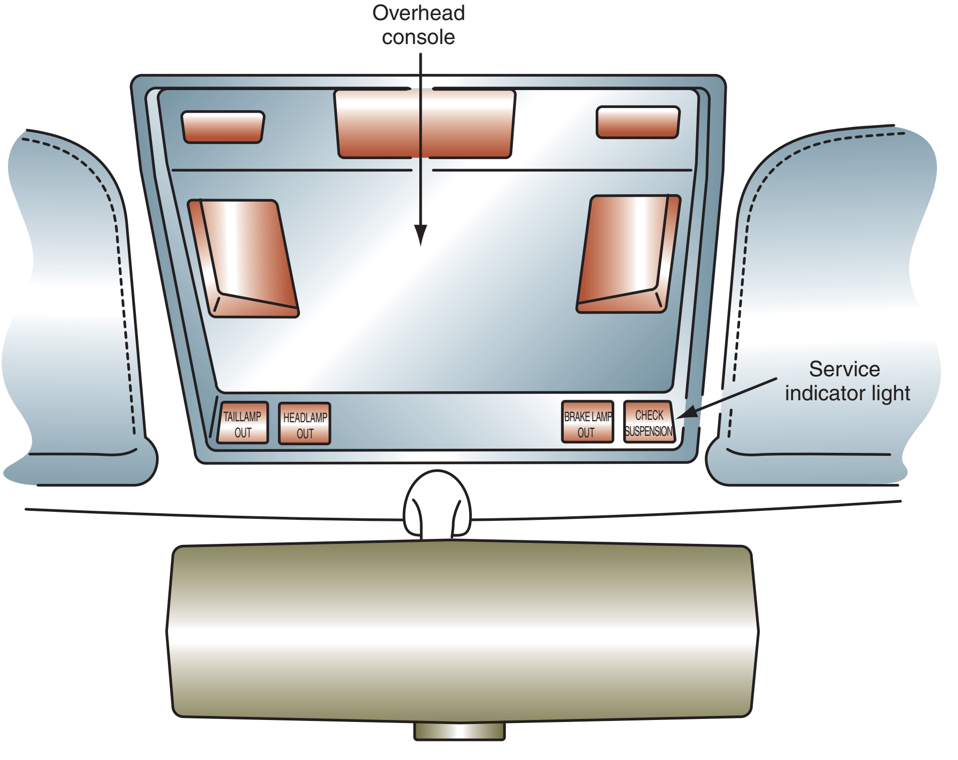

FIGURE 8-24 **Air suspension warning light.**

On some vehicles the air suspension warning light is replaced with a CHECK SUSPENSION message in the instrument panel message center. The suspension module provides a CHECK SUSPENSION message if an electrical defect occurs in the air suspension system. An AIR SUSPENSION SWITCHED OFF message appears in the message center if the air suspension switch is in the Off position.

Electronic Air Suspension System Operation

An electronically controlled suspension system may be called an active suspension system.

The operation of an air suspension system varies depending on the vehicle make and model year. The following section discusses typical air suspension operation.

Ignition Switch Off

The electronic air suspension system is fully operational for one hour after the ignition switch is turned from the Run to the Off position. During this time, lower vehicle commands are completed unless a height sensor was providing a high signal when the ignition switch was turned off. After a one-hour period, raise vehicle commands are acted upon and lower vehicle commands are ignored. The air compressor run time is limited to 15 seconds for rear springs and 30 seconds for front springs.

Ignition Switch in Run Position

When the ignition system has been in the Run position for less than 45 seconds, raise vehicle commands are completed immediately, but lower vehicle commands are ignored. If the ignition switch has been in the Run position for more than 45 seconds, the operation is as follows:

1. If a door is opened with the brake pedal released, raise vehicle commands are completed immediately, but lower vehicle commands are serviced after the door is closed. This action prevents an open door from catching on curbs or other objects.
2. If the doors are closed and the brake pedal is released, all commands are serviced by a 45-second averaging method to prevent excessive suspension height corrections on irregular road surfaces.
3. If the brake is applied and a door is open, raise vehicle commands are completed immediately, but lower vehicle commands are ignored.
4. When the doors are closed and the brake pedal is applied, all commands are ignored by the control module. If a command to raise the rear suspension is in progress under these conditions, this command will be completed. This action prevents correction of front end jounce while braking.

General Operation

When a height sensor sends a raise vehicle command to the control module and the other input signals are acceptable, the module grounds the compressor relay winding and starts the compressor. The module also opens the appropriate air spring valve to allow air flow into the air spring (Figure 8-25).

On non-computer-controlled suspension systems, the trim height may be called the curb riding height.

The rear air valve solenoids always operate together, but the front solenoids may be energized independently. When the correct chassis trim height is obtained, the control module opens the circuit from the compressor relay winding to ground and de-energizes the air spring valve. This action shuts off the compressor and traps the air in the air spring.

If a lower vehicle request is sent from a height sensor to the control module and the other input signals are acceptable, the control module opens the air vent valve and appropriate air spring valve. When this action occurs, air is released from the air spring until the correct trim height is obtained. The trim height signal from the height sensor to the module causes the module to close the air vent valve and the air spring valve.

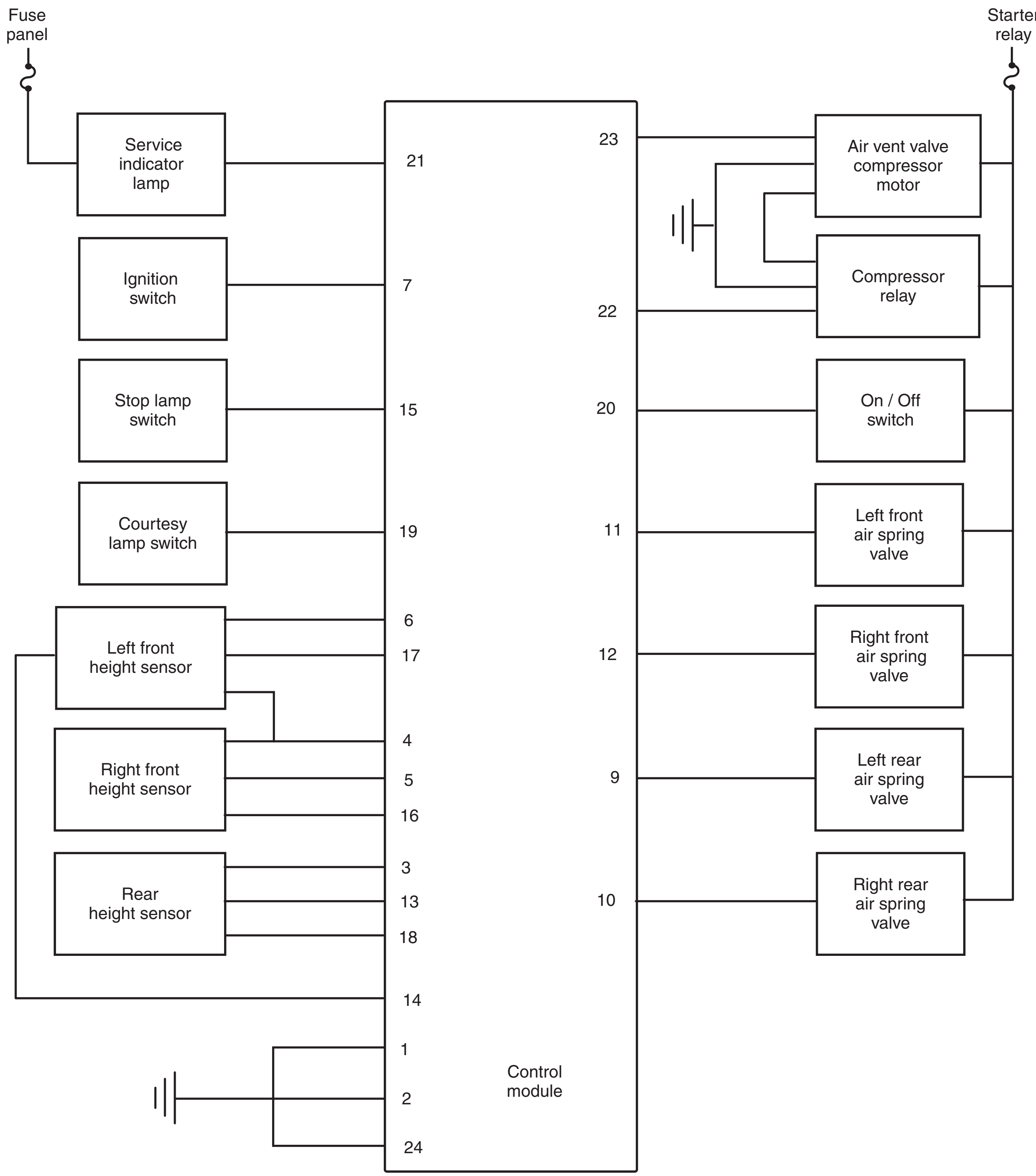

FIGURE 8-25 **Air suspension wiring diagram.**

Specific Control Module Operation

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Commands are completed by the module in this order: rear up, front up, rear down, front down. When the ignition switch is in the Run position and a command cannot be completed within three minutes, the module turns on the air suspension warning lamp. This lamp remains on until the ignition switch is turned off. On some older models all the control module memory is erased when the ignition switch is turned off. Therefore, the warning lamp

may not indicate a defect immediately if the ignition switch is turned from the Off to the Run position. When a system defect causes the module to illuminate the warning lamp with the ignition in the Run position, other commands may be completed by the module. Commands from the front and rear height sensors are never completed simultaneously.

If an electrical defect occurs in a modern air suspension system, a diagnostic trouble code (DTC) is set and retained in the suspension module memory. In these systems, DTCs are transmitted via the data links to the data link connector (DLC) under the instrument panel, and the DTCs may be displayed on a scan tool connected to the DLC.

Air Suspension System Design Variations

Rear Load-Leveling Air Suspension System

Some vehicles have air suspension on only the rear wheels, and these systems may be referred to as rear load-leveling air suspension systems. These air suspension systems have basically the same air springs, compressor and relay, On/Off switch, and rear height sensor as the air suspensions described previously. If additional weight is placed in the trunk, the rear height sensor signals the suspension control module to raise the rear suspension height to the specified trim height. When the extra weight is removed from the trunk, the suspension height is higher than specified, and the air suspension system lowers the rear trim height to the specified height.

Air Suspension System with Speed Leveling Capabilities

Some vehicles have an air suspension system on the front and rear wheels that is similar to the air suspension systems described earlier in this chapter. However, these systems have an input signal from the vehicle speed sensor (VSS) to the suspension module. On some vehicles the signal from the VSS is sent to the powertrain control module (PCM) that controls engine functions. The PCM transmits the VSS signal through the data links from the PCM to the suspension module. When the VSS signal indicates the vehicle is traveling above 65 mph (105 km/h), the suspension module opens the vent valve and spring solenoid valves to lower the suspension height a specific amount. Under this condition the vehicle is more dynamically efficient and this improves high-speed vehicle stability and fuel economy.

Special Air Suspension System Features on Four-Wheel-Drive Vehicles

Some four-wheel-drive vehicles with a conventional front torsion bar suspension and a leaf-spring rear suspension also have an air suspension system on all four wheels. These front and rear suspension systems maintain the specified ride height during two-wheel-drive operation. The air suspension system has the same components as described previously, except this air suspension system has front and rear air shock absorbers in place of air springs. An air solenoid is connected in the air line to each air shock absorber (Figure 8-26). The air shock absorbers also contain electrical solenoids that rotate the shock absorber valves and vary the ride firmness (Figure 8-27). This type of air suspension may be called an automatic ride control (ARC) system.

When driving on a smooth road surface in two-wheel drive, the suspension module positions the shock absorber valves to provide a soft ride. If the vehicle is driven on a rough road surface, the suspension's computer switches the shock absorber valves to the firm mode. When the driver selects four-wheel high mode, the suspension module starts the compressor and opens the air shock absorber valves, and increases the air shock absorber pressure until the suspension trim height is raised 1 in. (25.4 mm). If the vehicle speed exceeds 58 mph (93 km/h), the module returns the suspension height to the specified trim height. If the driver selects the four-wheel low mode, the suspension module operates the compressor and air

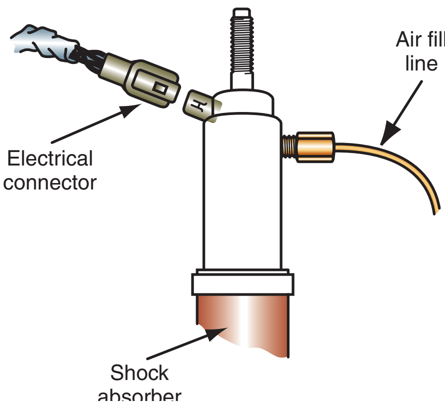

FIGURE 8-26 **Electrical and air fill line connections to the shock absorber.**

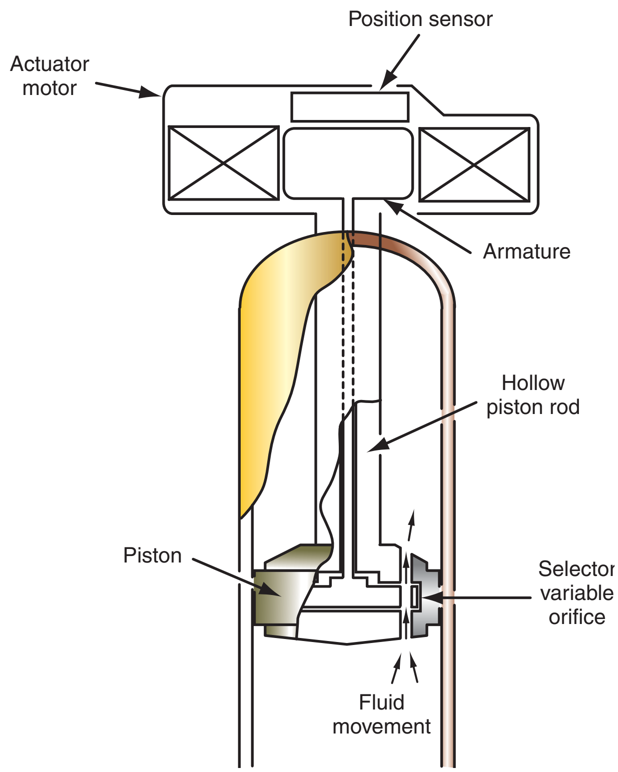

FIGURE 8-27 **Strut actuator.**

shock absorber valves to increase the trim height 2 in. (50.8 mm). If the vehicle speed exceeds 30 mph (48 km/h in the four-wheel low mode), the module adjusts the suspension height to 1 in. (25.4 mm) above the specified trim height.

Vehicle Dynamic Suspension System

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Some SUVs are equipped with a **vehicle dynamic suspension (VDS)** system that is similar to the air suspension systems described previously in this chapter. The VDS system has these components:

1. Off/On service switch
2. Two front height sensors
3. One rear height sensor
4. Compressor with internal vent solenoid and air dryer
5. Control module
6. Air lines
7. Front and rear combined air springs and shock absorbers
8. Four air spring solenoids
9. Compressor relay

When increased air pressure is required in an air spring, the control module closes the compressor relay, starts the compressor, and opens the solenoid on the appropriate air spring. To vent air from an air spring, the control module must energize the air spring solenoid and the vent valve. The VDS system has three operating modes:

1. The kneel mode is provided by the suspension module when the ignition switch is in the Off or Lock position and all doors, liftgate, and liftgate glass are closed. In this mode the module opens the vent valve and air spring valves, and slowly reduces the suspension height to 1 in. (25.4 mm) below the specified trim height. This mode improves the ease of entering and exiting the vehicle.

2. When the ignition switch is On, and the transmission is initially shifted into Drive or Reverse, and all the doors, liftgate, and liftgate glass are closed, the VDS switches from the kneel mode to the trim mode, which provides the normal trim height. The VDS system also switches to the trim height mode if the module detects a vehicle speed above 15 mph (24 km/h). Transitions between modes require approximately 30 to 45 seconds.
3. On four-wheel-drive models the off-road height mode is provided when the driver selects the four-wheel low mode and the vehicle speed is less than 25 mph (40 km/h). In this mode the module starts the compressor and opens the air spring valve to increase the air spring pressure until the suspension height is 1 in. (25.4 mm) above the specified trim height.

The VDS system also maintains the specified trim height in relation to the weight placed in the vehicle. If a heavy load is placed in the rear of the vehicle, the rear height sensors transmit low trim height signals to the module, and the module opens the rear air spring solenoids and starts the compressor to restore the proper rear suspension trim height. The system stores front and rear trim height when a door or the rear liftgate is opened. The module maintains this suspension height even if weight is added to or removed from the vehicle. When all the doors, liftgate, and liftgate glass are closed, the system returns to normal operation. The VDS system makes limited height adjustments for 40 minutes after the ignition switch is turned Off.

Electronic Suspension Control (ESC) System

General Description

The **electronic suspension control (ESC) system** controls damping forces in the front struts and rear shock absorbers in response to various road and driving conditions. The ESC system changes shock and strut damping forces in 1 to 12 milliseconds, whereas other suspension damping systems require a much longer time interval to change damping forces. It requires about 200 milliseconds to blink your eye. This gives us some idea how quickly the ESC system reacts. On some older models the ESC system may be called a continuously variable road sensing suspension (CVRSS).

The powertrain control module (PCM) is a computer that controls such output functions as electronic fuel injection, spark advance, emission devices, and transaxle shifting.

The ESC module receives inputs regarding vertical acceleration, wheel-to-body position, speed of wheel movement, vehicle speed, and lift/dive (Figure 8-28). The CVRSS module

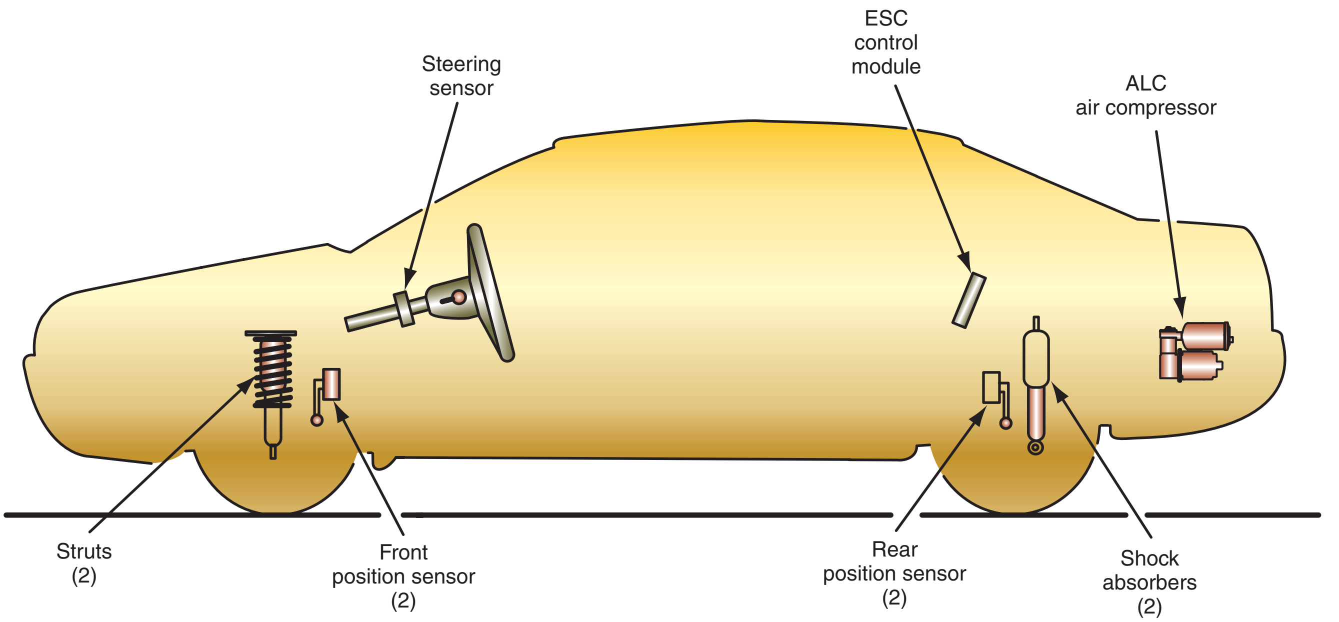

FIGURE 8-28 **Electronic suspension control (ESC) system.**

evaluates these inputs and controls a solenoid in each shock or strut to provide suspension damping control. The solenoids in the shocks and struts can react much faster compared with the strut actuators explained previously in some systems.

The ESC module also controls the speed-dependent steering system called MagnaSteer® and the automatic level control (ALC). This MagnaSteer® system is similar to the electronic variable orifice (EVO) steering explained in Chapter 12 under conventional and electronic rack-and-pinion steering gears. The ALC system controls the air pressure in the rear air shock absorbers to maintain the proper rear suspension height. The ALC system is similar to the rear load-leveling suspension system explained previously in this chapter.

Inputs

Position Sensors. A **wheel position sensor** is mounted at each corner of the vehicle between a control arm and the chassis (Figures 8-29 and 8-30). These sensor inputs provide analog voltage signals to the ESC module regarding relative wheel-to-body movement and the velocity of wheel movement (Figure 8-31). The rear position sensor inputs also provide rear suspension height information to the ESC module, and this information is used by the module to control the rear suspension trim height. All four position sensors have the same design. The wheel position sensors may be linear-type or rotary-type.

Accelerometer. An **accelerometer** is mounted on each corner of the vehicle. These inputs send information to the ESC module in relation to vertical acceleration of the body. The front accelerometers are mounted on the strut towers (Figure 8-32), and the rear accelerometers are located on the rear chassis near the rear suspension support (Figure 8-33). All four accelerometers are similar in design, and they send analog voltage signals to the ESC module (Figure 8-34). On some later model vehicles, the four accelerometers are replaced by a single accelerometer under the driver's seat. On other late-model vehicles the accelerometer(s) are eliminated.

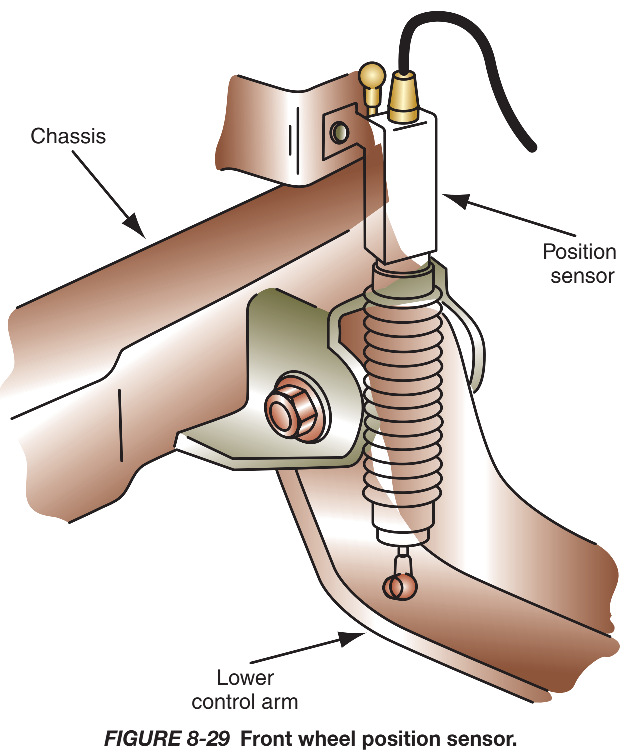

FIGURE 8-29 **Front wheel position sensor.**

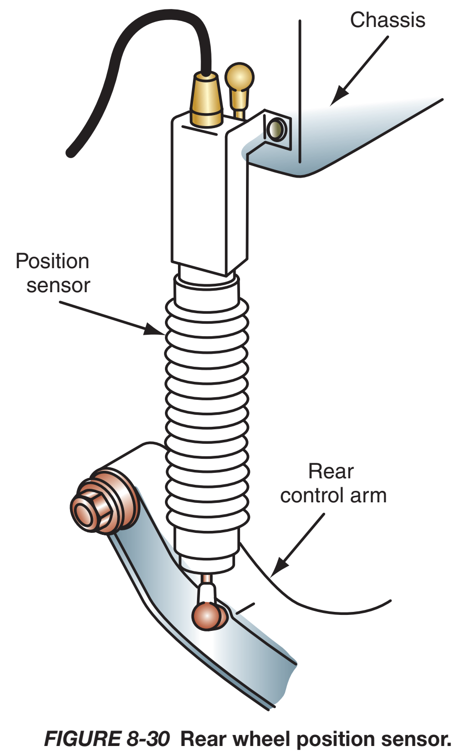

FIGURE 8-30 **Rear wheel position sensor.**

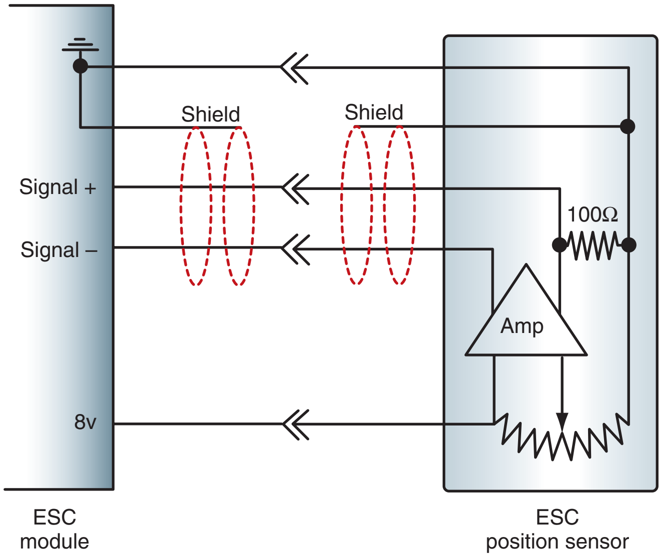

FIGURE 8-31 **Position sensor internal design and wiring diagram.**

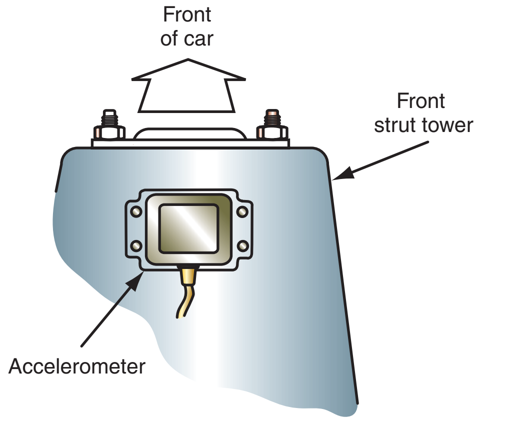

FIGURE 8-32 **Front accelerometer mounting location.**

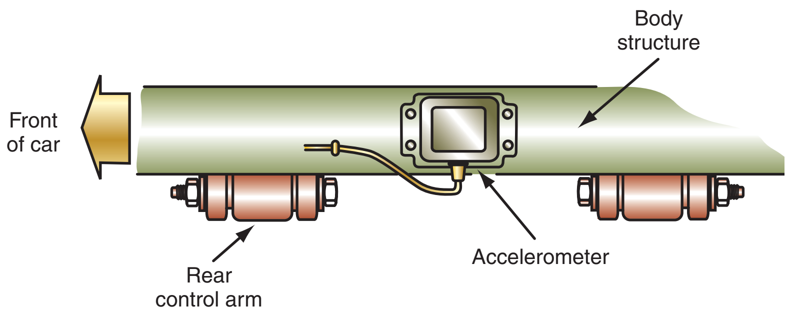

FIGURE 8-33 **Rear accelerometer position.**

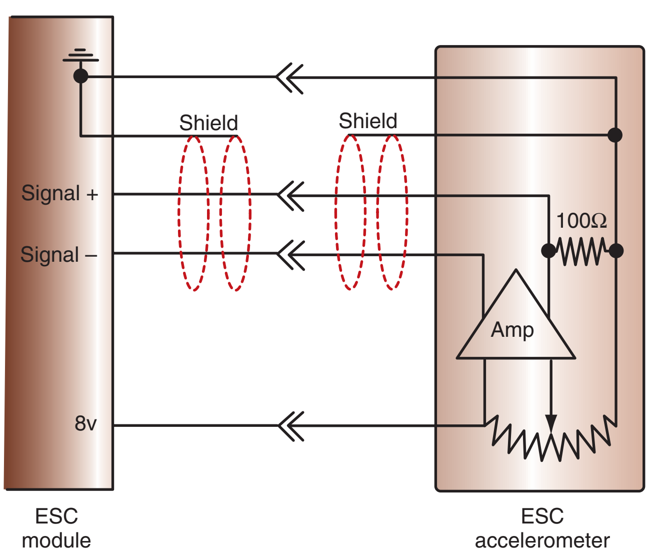

FIGURE 8-34 **Accelerometer internal design and wiring diagram.**

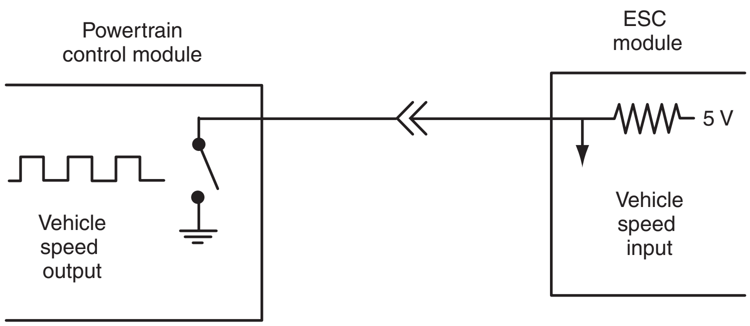

FIGURE 8-35 **The vehicle speed sensor (VSS) signal is sent to the powertrain control module (PCM) and transmitted to the ESC module.**

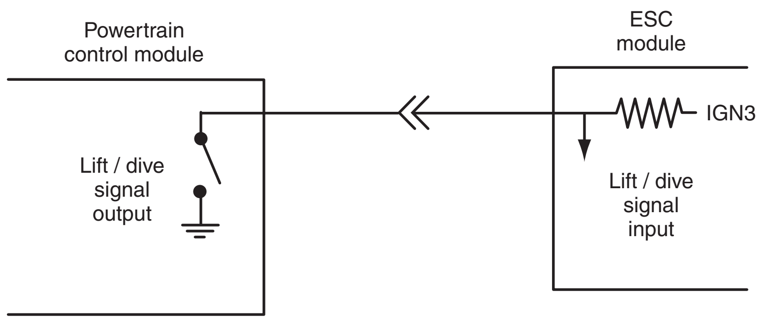

FIGURE 8-36 **The lift-dive signal is sent from the powertrain control module (PCM) to the ESC module.**

Vehicle Speed Sensor. The **vehicle speed sensor (VSS)** is mounted in the transaxle. This sensor sends a voltage signal to the powertrain control module (PCM) in relation to vehicle speed (Figure 8-35). The VSS signal is transmitted via data links from the PCM to the ESC module.

Lift/Dive Input. The **lift/dive input** is sent from the PCM to the ESC module (Figure 8-36). Suspension lift information is obtained by the PCM from the throttle position, vehicle speed, and transaxle gear input signals. The PCM calculates suspension dive information from the rate of vehicle speed change when decelerating.

Electronic Suspension Control Module

Electronic suspension control module contains three microprocessors that control the ESC, Magnsateer® system, and automatic level control (ELC). The ESC module is mounted on the right side of the electronics bay in the trunk. Extensive self-diagnostic capabilities are programmed into the ESC module.

Outputs

Shock Absorbers and Struts with Magneto-Rheological (MR) Fluid. The shock absorbers or struts in the ESC system contain magneto-rheological (MR) fluid. This fluid is a synthetic fluid containing suspended iron particles. An electric winding is mounted in each shock absorber housing, and the ends of each shock absorber winding are connected to the ESC module. When the shock absorber windings are not energized by the ESC module, the iron particles in the MR fluid are dispersed randomly. Under this condition the MR fluid has a mineral oil–like consistency, and this fluid flows easily through the shock absorber orifices to provide soft ride quality.

When the ESC module energizes the shock absorber windings, the magnetic field around the winding aligns the iron particles in the MR fluid into thick fibrous structures. In this

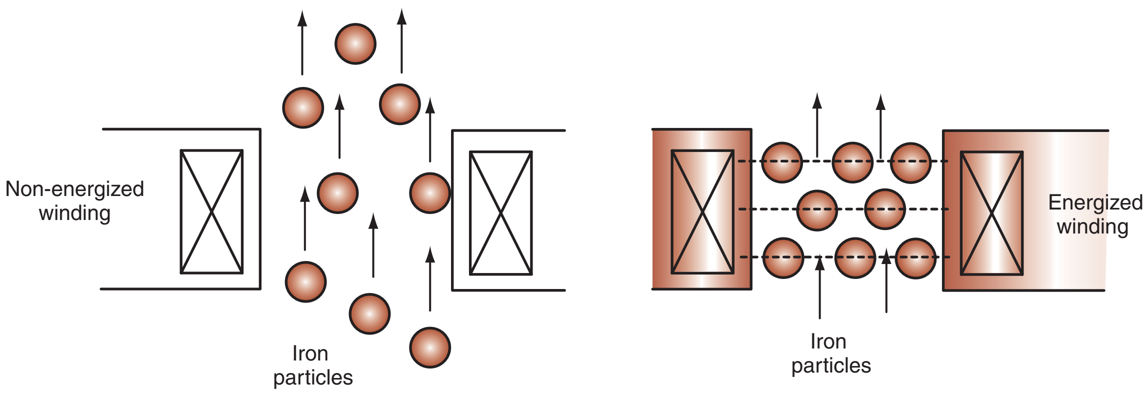

FIGURE 8-37 **Magneto-rheological fluid action in a strut or shock absorber.**

condition the MR fluid has a jelly-like consistency that does not flow easily through the shock absorber orifices (Figure 8-37). This fluid change provides firm ride quality. When a shock absorber coil is energized, the amount of attraction between the fibrous particles is proportional to the magnetic field strength surrounding the shock absorber winding, and this field strength is controlled by the current flow through the winding. The computer provides very precise control of the current flow through each shock absorber or strut winding to supply a very broad shock absorber and strut damping range. Based on the wheel position sensor and other inputs, the ESC module can energize each individual shock absorber winding many times per second with a **pulse width modulated (PWM)** signal. Therefore the ESC system with magneto-rheological fluid in the shock absorbers or struts provides an almost infinite variation in shock absorber damping. The ESC system can change the damping characteristics of the MR fluid in 1 millisecond. The ESC system may be called a **MagneRide system**.

A **pulse width modulated** signal is a signal with a variable on time that may be used by a computer to control an output.

A **MagneRide** suspension system has magneto-rheological fluid in the shock absorbers.

The ESC system with MR fluid in the shock absorbers or struts provides greatly improved control of pitch and body roll motions, which supplies better road-holding capabilities, steering control, ride quality, and safety. Recent updates to the ESC system with MR fluid in the shock absorbers or struts include the following:

1. Improved computer software to provide a broader damping range and more precise control of the shock actuators.
2. Expanded sensor inputs including brake pressure, vehicle yaw rate, steering angle, and engine torque.
3. Improved computer networks to allow increased and faster data transmission.

These updates provide improved vehicle dynamics and ride quality without any increase in packaging or weight.

Damper Solenoid Valves. On some older models each strut or shock damper contains a solenoid that is controlled by the ESC module. Each **damper solenoid valve** provides a wide range of damping forces between soft and firm levels. Strut or shock absorber damping is controlled by the amount of current supplied to the damper solenoid in each strut or shock absorber. Battery voltage and ignition voltage are supplied through separate fuses to the ESC module (Figure 8-38). If the damper solenoids are not energized, the struts provide minimum damping force. When the damper solenoids are energized, the struts provide increased damping force for a firmer ride. The ESC module switches the voltage supplied to the damper solenoid in each strut on and off very quickly with a 2.0 kilohertz pulse width modulated (PWM) action. If the ESC module keeps the damper solenoid in a strut energized longer on each cycle, current flow is increased through the strut damper solenoid. Under this condition, strut damping force is increased to provide a firmer ride. The ESC module provides precise, variable control of the current flow through each strut or shock damper solenoid to achieve a wide range of damping forces in the struts. The ESC system can change the shock absorber damping forces in 10 to 12 milliseconds.

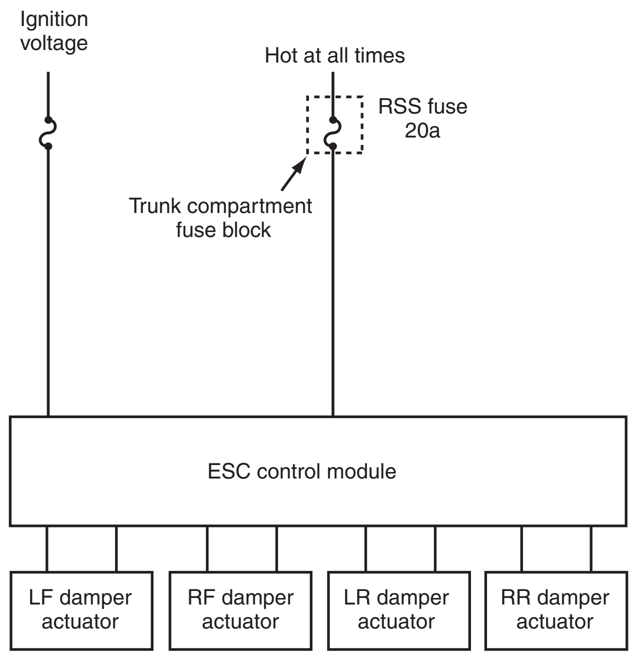

FIGURE 8-38 **Strut damper solenoid circuit.**

Each damper solenoid is an integral part of the damper assembly and is not serviced separately. The ESC system operates automatically without any driver-controlled inputs. The fast reaction time of the ESC system provides excellent control over ride quality and body lift or dive, which provides improved vehicle stability and handling. Since the position sensors actually sense the velocity of upward and downward wheel movements and the damper solenoid reaction time is 11 to 12 milliseconds, the ESC module can react to these position sensor inputs very quickly. For example, if a road irregularity drives a wheel upward, the ESC module switches the damper solenoid to the firm mode before that wheel strikes the road again during the downward movement.

Resistor Module. In some older models, the resistor module contains four resistors encapsulated in a ceramic material. This resistor module is mounted in the right rear quarter panel inside the trunk (Figure 8-39).

When the ESC module switches a damper solenoid on, the module provides a direct ground for the solenoid, and full voltage is dropped across the solenoid winding to energize the solenoid very quickly. Under this condition, a higher current flow is supplied through the damper solenoid winding and the ESC module to ground. Since it is undesirable to maintain this higher current flow through the damper solenoid for any longer than necessary, the ESC module switches a resistor in the resistor module into the damper solenoid circuit after this circuit is energized for 15 milliseconds. On later model vehicles, the resistor module is discontinued because the ESC module controls the strut damper solenoids with a PWM signal.

This resistor reduces the voltage drop across the damper solenoid, which lowers the current flow. This lower current flow is high enough to hold the damper solenoid in the On mode. Each damper solenoid circuit is basically the same.

Rear Automatic Level Control

The **automatic level control (ALC)** system maintains the rear suspension trim height regardless of the rear suspension load. If a heavy object is placed in the trunk, the rear wheel position sensors send below trim height signals to the ESC module. When this signal is received, the ESC module grounds the ALC relay winding and closes the relay contacts that supply voltage to the compressor motor (Figure 8-40).

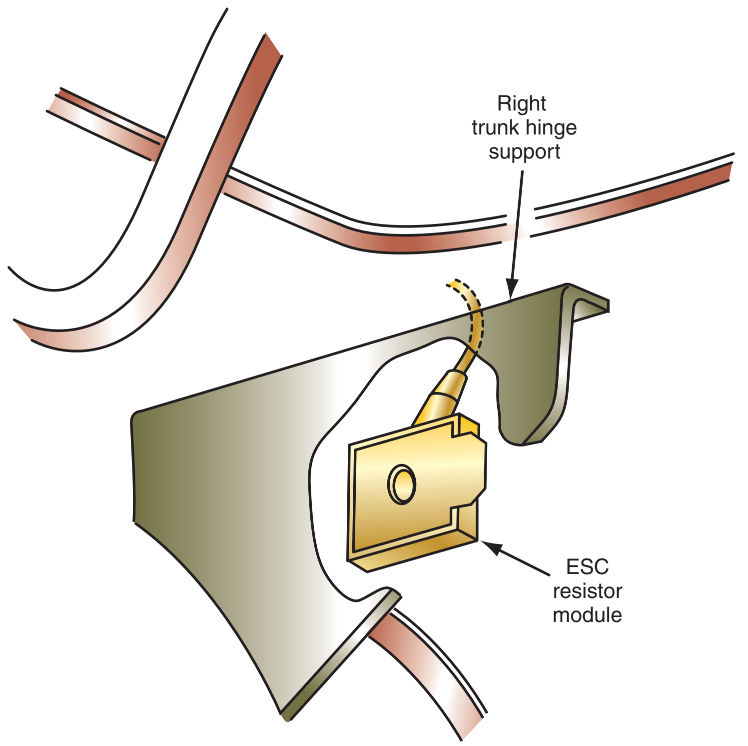

FIGURE 8-39 **Resistor module mounting location.**

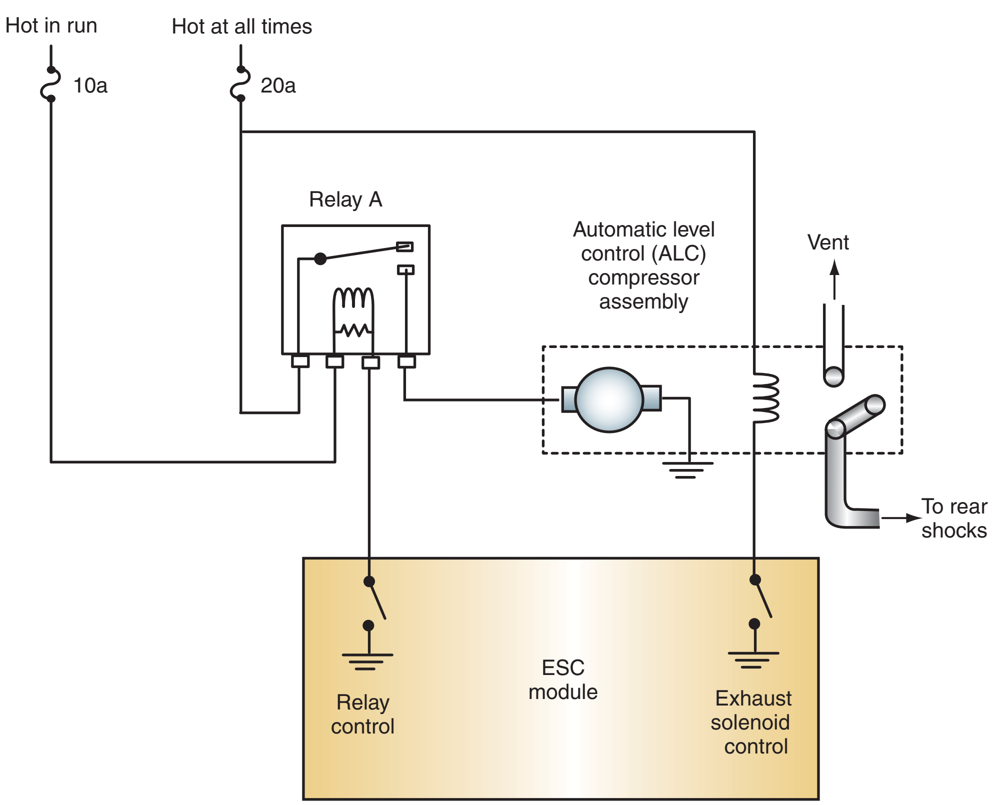

FIGURE 8-40 **Rear automatic level control (ALC).**

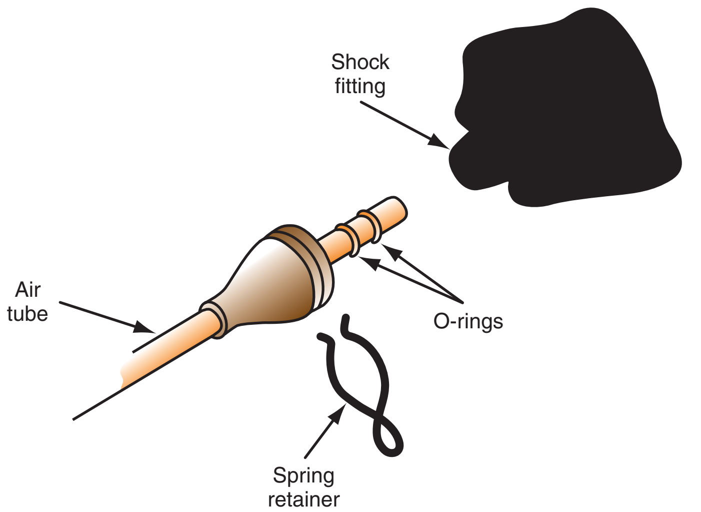

FIGURE 8-41 **Nylon air line and rear shock air line fitting.**

Once the compressor starts running, it supplies air through the nylon lines to the rear air shocks and raises the rear suspension height (Figure 8-41). When trim height signals are received from the rear wheel position sensors, the ESC module opens the compressor relay winding circuit and stops the compressor.

If a heavy object is removed from the trunk, the rear wheel position sensors send above trim height signals to the ESC module. Under this condition, the ESC module energizes the exhaust solenoid in the compressor assembly, and this action releases air from the rear air shocks. When the rear wheel position sensors send rear suspension trim height signals to the ESC module, this module shuts off the exhaust solenoid.

An independent ALC system is used on cars without the ESC system. In these systems, the computer is not required and a single suspension height sensor is used. This height sensor contains electronic circuits that control the compressor relay and the exhaust solenoid. This electronic circuit limits the compressor run time and the exhaust solenoid on time to 7 minutes.

Speed Sensitive Steering System

On some models the ESC module operates a solenoid in the **speed sensitive steering (SSS) system** to control the power steering pump pressure in relation to vehicle speed (Figure 8-42). This action varies the power steering assist levels.

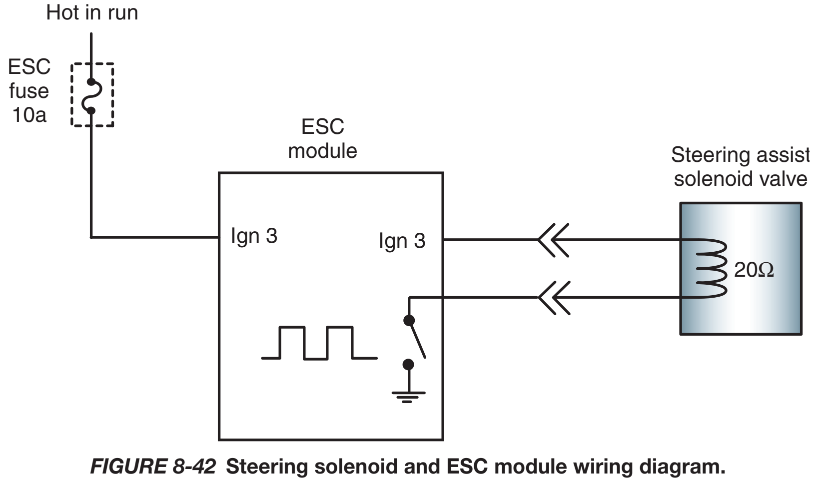

FIGURE 8-42 **Steering solenoid and ESC module wiring diagram.**

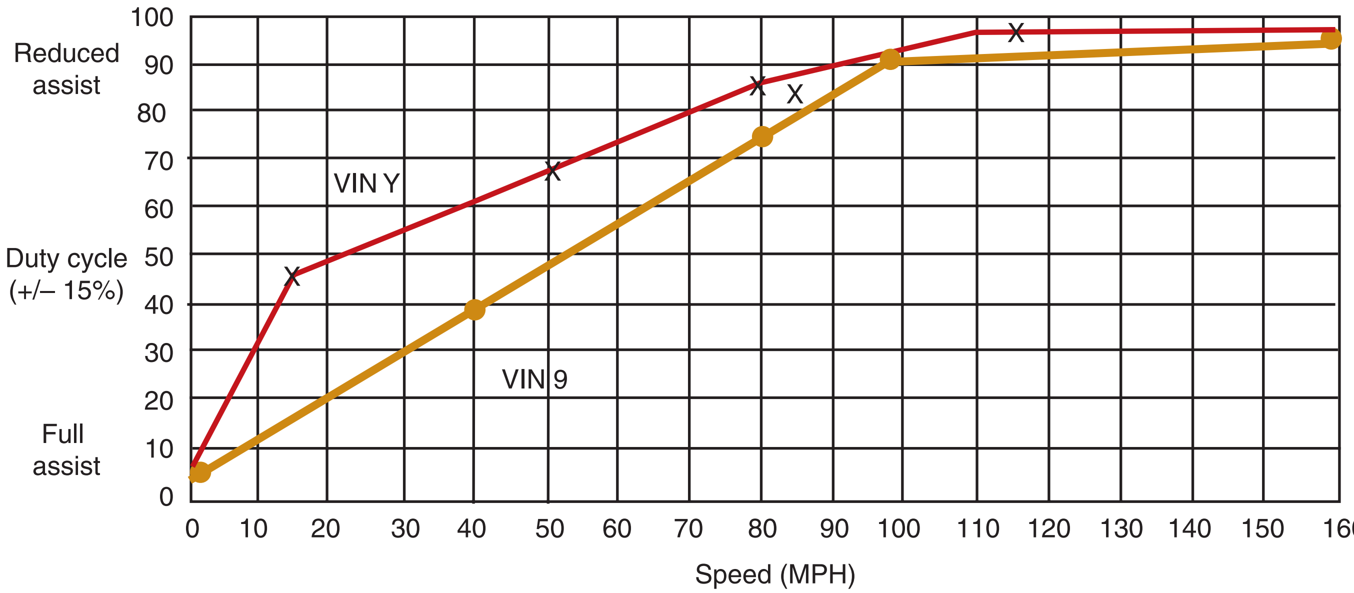

FIGURE 8-43 **Power steering assist in relation to vehicle speed.**

The ESC module varies the on time of the steering solenoid. This action may be referred to as pulse width modulation (PWM). When the solenoid is in the Off mode, the power steering pump supplies normal power assist. Below 10 mph (16 km/h), the computer operates the steering solenoid to provide full power steering assist (Figure 8-43). This action reduces steering effort during low-speed maneuvers and parking.

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As the vehicle speed increases, the ESC module operates the steering solenoid so the power steering assist is gradually reduced to provide increased road feel and improved handling.

On later model cars, the speed sensitive steering (SSS) is called speed dependent steering or MagnaSteer®. The module that controls the MagnaSteer® is contained in the electronic brake and traction control module (EBTCM).

Integrated Electronic Systems and Networks

Advantages of Integrated Electronic Systems and Networks

With the rapid advances in electronic technology, there is a trend toward integrating some computer-controlled automotive systems. Rather than having a separate computer for each electronic system, several of these systems may be controlled by one computer. Vehicles without any integrated electronic systems may have many individual modules and computers. Because computers must have some protection from excessive temperature changes, extreme vibration, magnetic fields, voltage spikes, and oil contamination, it becomes difficult for engineers to find a suitable mounting place for this large number of computers. Integration of several electronic systems into one computer solves some of these computer mounting problems and reduces the length of wiring harness. The ESC system explained in this chapter is an example of an integrated electronic system with suspension ride control, suspension level control, and speed sensitive steering controlled by one computer.

Another method of reducing the number of wires on a vehicle is to interconnect many of the on-board computers with data links. A data link system may be referred to as a **network**. Some input sensor signals may be required by several computers. For example, on some vehicles the VSS signal is required by the PCM, suspension computer, transmission computer, cruise control module, and throttle control module. On many vehicles the VSS is hardwired to the PCM, and then the PCM relays the VSS signal to the other computers via the network.

In a **network** several computers are interconnected by data links.

Many vehicles now have a front control module mounted near the front of the vehicle and a rear control module mounted near the rear of the vehicle. These vehicles also have a body computer module (BCM). The BCM, PCM, front and rear control modules, and other modules are interconnected by a network. On some models the BCM is called a generic electronic module (GEM). The light switch is hard wired to the BCM. When the light switch is turned on, a voltage signal is sent to the BCM, and the BCM relays the appropriate LIGHTS ON message through the network to the front and rear control modules. These modules are hard wired to the lights. When the front and rear control modules receive a specific LIGHTS ON message, these modules turn on the appropriate front and rear lights. Connecting the BCM and the front and rear control modules via a networks reduces the number of wires between the light switch and the front and rear lights.

Some vehicles equipped with power windows and power door locks have a module in each door. These modules are hard wired to the window motor and door lock controls in each door. These door modules are connected by a network to the BCM that is usually mounted under the dash. The window and door lock control switches are hard wired to the BCM. When a WINDOW DOWN signal is sent from a window switch to the BCM, the BCM relays this signal through the network to the proper door module. When the door module receives the WINDOW DOWN signal, it supplies voltage to the window motor in the proper direction to roll the window down. Connecting the door modules to the BCM by a network greatly reduces the number of wires connected from the door switches into each door, and this design reduces wiring harness size and weight. Networks also reduce some of the problems associated with wiring harnesses.

A Bit of History

In 1996, the typical vehicle had 6 electronic control units (ECUs). In 2008, some luxury vehicles had up to 120 modules, 5 main networks, and 12 to 14 sub-networks depending on the onboard electronic equipment.

Types of Networks

One type of network system introduced in the early 1980s is the Chrysler Collision Detection (CCD) network. The CCD system has a twisted pair of wires connected between the PCM, BCM, transmission control module (TCM), air bag control module (ACM), electromechanical instrument cluster (MIC), and vehicle theft security system (VTSS) module. On some models the CCD system is also connected to the data link connector (DLC), allowing the computers in the system to communicate with a scan tool connected to the DLC. The network system may be called a data bus. The CCD system operates at 2.5 V.

Another type of network system introduced in the 1980s is the universal asynchronous receive and transmit (UART) system. The UART data links are connected between various on-board computers and the DLC. The UART system operates at 5 V and transmits data at 8.2 kilobits per second. When sending data, the UART system toggles the voltage from 5 V to ground at a fixed bit pulse width. At rest the UART network system has 5 V.

With the implementation of on-board diagnostic II (OBDII) systems in 1996, improved communication was required between the PCM, other computers, and the scan tool. Class 2 networks were installed to meet this demand. Class 2 networks transmit data at 10.4 kilobits per second, and transmit data by toggling the voltage from 0 to 7 V. At rest this network system has zero volts. The programmable communication interface (PCI) networks were also introduced on some vehicles to increase the data communication requirements. The PCI network system is a single wire system. Figure 8-44 illustrates a comparison between PCI and CCD network systems. The PCI system operates between 0 V and 6 V to 8 V. Communication on a network system is accomplished by sending a group of 0 and 1 signals (Figure 8-45). A long voltage pulse at a high voltage and a short pulse at a low voltage represent a 0 signal. Conversely, a short pulse at a high voltage and a long pulse at a low voltage indicate a 1 signal (Figure 8-46).

Many vehicles are now equipped with controller area network (CAN) systems. A local area network (LAN) system is similar to the CAN system, and the LAN system is used on a significant number of vehicles. Some vehicles have a low-speed LAN system and a separate

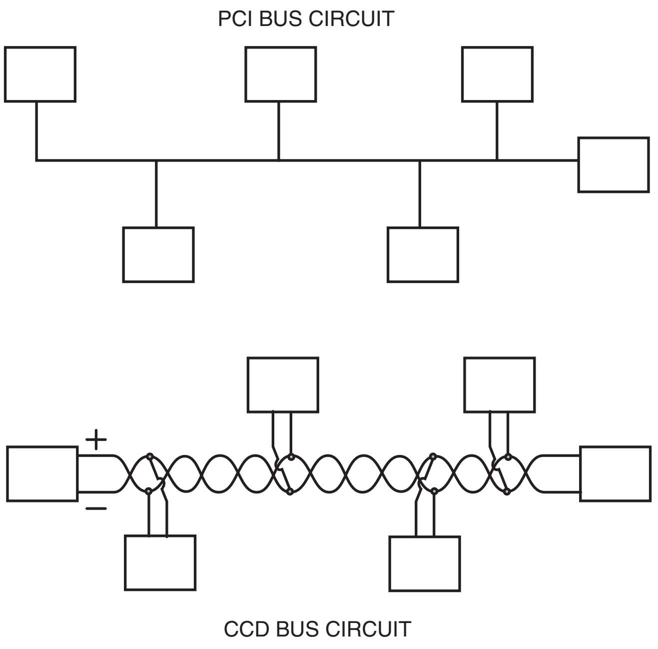


FIGURE 8-44 **Comparison between PCI and CCD data link systems.**

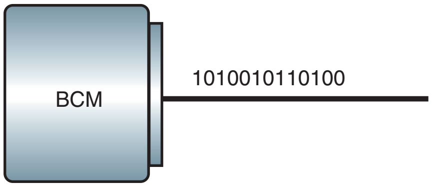


FIGURE 8-45 **A data link system transmits data by using a group of 0 and 1 signals.**

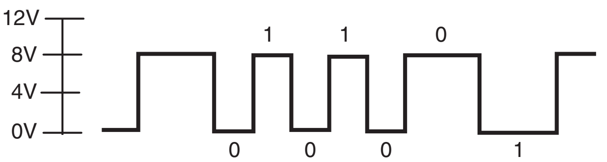


FIGURE 8-46 **Voltage level and duration required for 0 and 1 signals.**

high-speed LAN system (Figure 8-47). The low-speed LAN system interconnects modules for applications such as door locks, window motors, HVAC, and radio. The low-speed LAN system is a single-wire system. The high-speed LAN system interconnects modules such as the PCM, transmission, antilock brake modules, and suspension modules. The high-speed LAN system is a two-wire system that operates at 500 kilobits per second. The greatly increased data transmission speed capabilities of the LAN system enhances the communication between various computers in the system and the scan tool. Other high-speed data

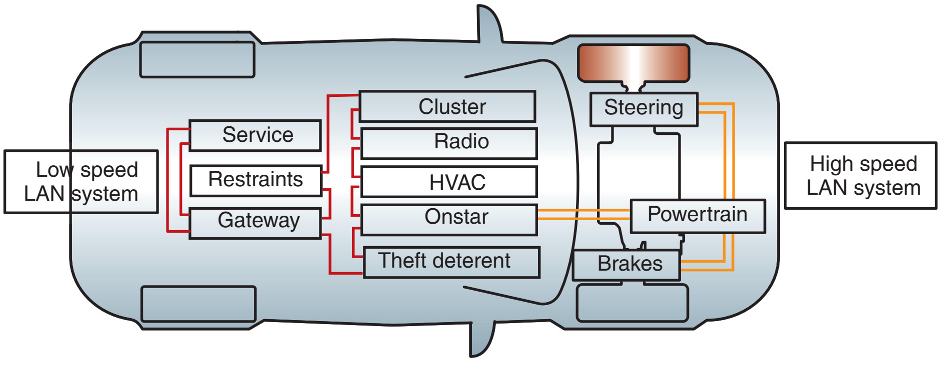


FIGURE 8-47 **Low-speed LAN and high-speed LAN data link systems.**

link systems on modern vehicles include FlexRay and local interconnect network (LIN). The FlexRay data link system transmits data at 10 megabits per second (Mbps). The Byteflight network used on some luxury cars has much in common with the FlexRay network. The network systems on a current sport utility vehicle (SUV) are shown in Figure 8-48. Some networks, such as the one illustrated in Figure 8-48, have a gateway module. The gateway module changes and directs the signals to go to the appropriate network within the complete network system. The gateway module is often combined within one of the other network computers.

Some networks, such as CAN, contain terminators located at both ends of the network. The terminators are usually positioned inside some of the network computers. Terminators provide electrical resistance to absorb data and prevent this data from being transmitted back into the network.

Most luxury vehicles presently have a media oriented systems transport (MOST) network system in which the computers are interconnected by fiber-optic data links. The MOST system transmits data at 150 megabits per second. The data transmission rate depends on the model year of the vehicle and data link system. For example, early model MOST systems transmitted data at 22.6 Mbps and current MOST systems transmit data at 150 Mbps. This high data transmission speed is required on vehicles with navigation systems, CD changers, video systems, and satellite radios. The MOST system greatly reduces the number of wires in the wiring harnesses, but is more expensive compared to a network interconnected by wires.

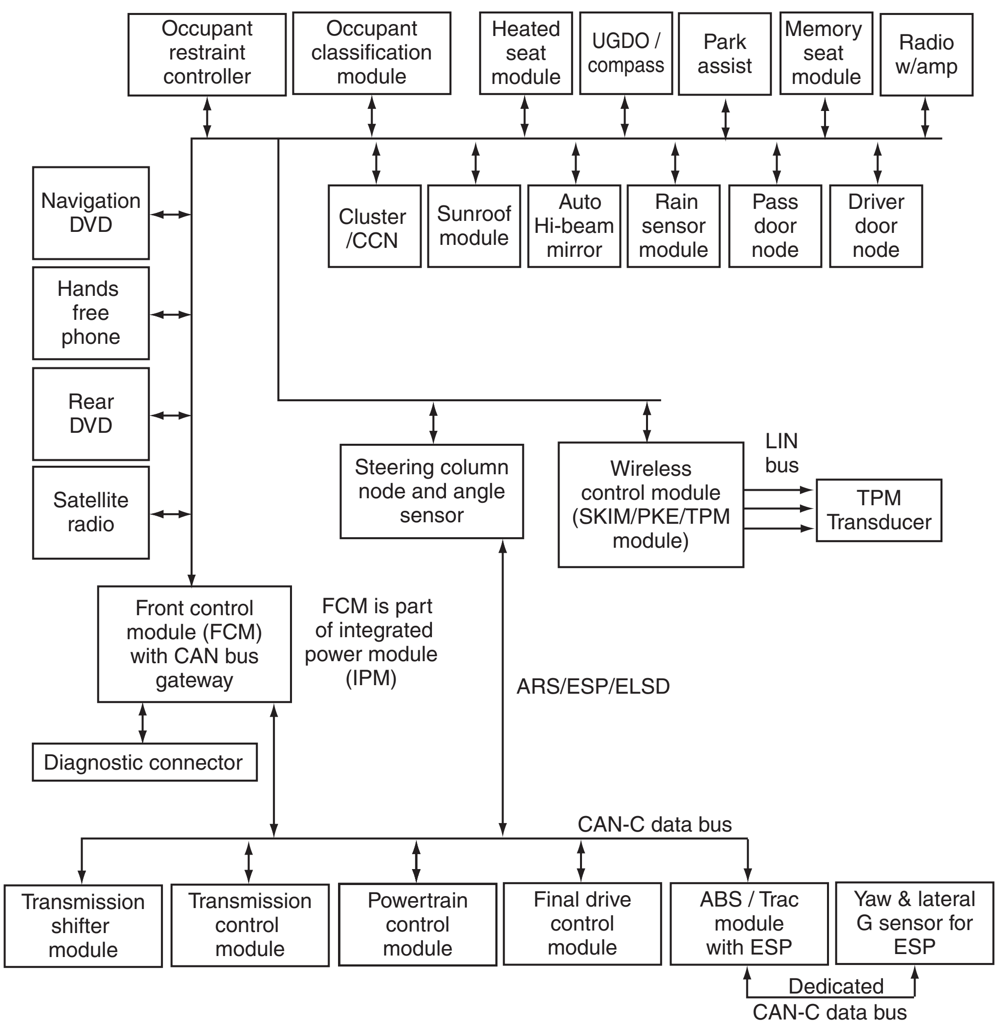


FIGURE 8-48 **Data link systems on a current SUV.**

Networks have collision resolution (CR) capabilities to prevent data collisions. The CR system varies depending on the network. In a single-wire CAN system, the system voltage is high when not transmitting data. When any computer wants to transmit data, it initiates a low voltage condition to begin transmission. As explained previously in this chapter, the data is a series of low and high voltages. The low voltage signal is the dominant voltage bit and the high voltage signal is the recessive voltage bit. The CR system uses the dominant and recessive voltage bits to determine transmission priority. If two computers transmit data at the same time, the CR system will recognize the computer with the most dominant bits and give priority to that computer. The low priority computer stops its communication, and the high priority computer continues data transmission. In a typical network, air bag, antilock brake, and suspension computers have high priority compared with audio computers.

AUTHOR'S NOTE: When diagnosing suspension systems and other electronic systems on modern vehicles, the scan tool you are using must be compatible with the networks and computers on the vehicle being diagnosed. The PCM in one current luxury car contains three 32-bit microprocessors that can perform 200 million calculations per second. The scan tool must be able to receive and transmit data at the same speed as the network system. Many older scan tools will not be updated so they are compatible with the CAN, LAN, and MOST network systems.

Vehicle Stability Control

Many vehicles manufactured in recent years are equipped with a vehicle stability control system. A **vehicle stability control system** provides improved control if the vehicle begins to swerve sideways because of slippery road surfaces, excessive acceleration, or a combination of these two conditions. Therefore, a vehicle stability control system provides increased vehicle safety. Vehicle stability control systems have various brand names depending on the vehicle manufacturer. For example, on General Motors vehicles the vehicle stability control system is called **Stabilitrak®**. The Stabilitrak® system is available on many General Motors cars and some SUVs. The module that controls the Stabilitrak® system is combined with the **antilock brake system (ABS)** module and **traction control system (TCS)** module (Figure 8-49). This three-in-one module assembly is referred to as the **electronic brake**

The **antilock brake system (ABS)** prevents wheel lockup during a brake application.

The **traction control system (TCS)** prevents drive wheel slippage.

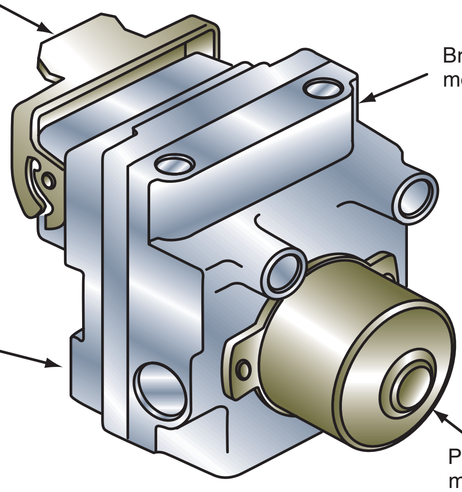


FIGURE 8-49 **The electronic brake and traction control module (EBTCM) contains the antilock brake system (ABS), traction control system, and stability control modules.**

The **electronic brake and traction control module (EBTCM)** controls ABS, TCS, and Stabilitrak® functions.

The **steering wheel position sensor** supplies a voltage signal in relation to the amount and speed of steering wheel rotation.

The **brake pressure modulator valve (BPMV)** controls brake fluid pressure to the wheel calipers or cylinders.

The **steering wheel position sensor** supplies a voltage signal in relation to the amount and speed of steering wheel rotation.

and traction control module (EBTCM). The EBTCM is attached to the **brake pressure modulator valve (BPMV)** and this assembly is mounted in the left front area in the engine compartment. A data link is connected between all the computers including the EBTCM and the ESC module (Figure 8-50). The combined EBTCM and ESC systems may be referred to as the integrated chassis control system 2 (ICCS2). Some sensors such as the **steering wheel position sensor (SWPS)** are hard-wired to both the EBTCM and the ESC module (Figure 8-51). The signals from other sensors may be sent to one of these modules and then transmitted to the other module on the data link. The data link also transmits data from these modules to the instrument panel cluster (IPC) during system diagnosis. This allows the IPC to display diagnostic information.

This book is concerned with suspension and steering systems. Because the stability control system operates in cooperation with the ABS and TCS systems, a brief description of these systems is necessary.

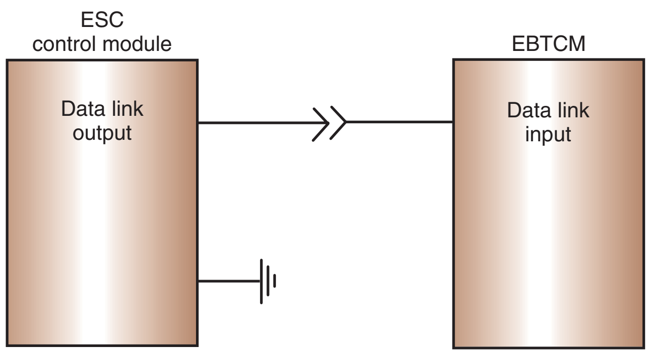


FIGURE 8-50 **Data link between the EBTCM and ESC modules.**

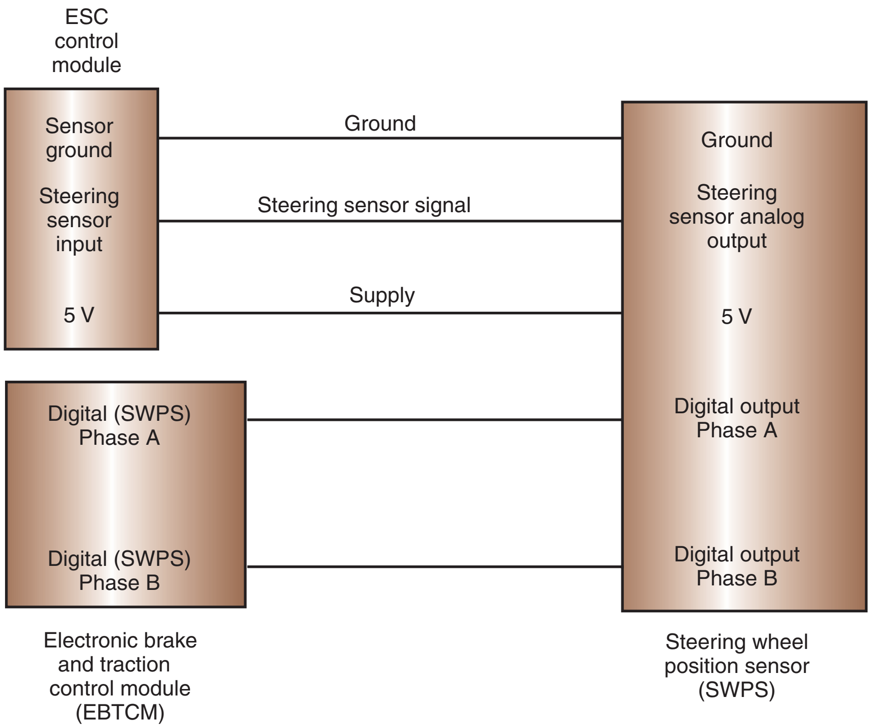


FIGURE 8-51 **The steering wheel position sensor (SWPS) is connected to both the ESC module and the EBTCM.**

AUTHOR'S NOTE: Statistics compiled by the National Highway Traffic Safety Administration (NHTSA) indicate that stability control systems can reduce the incidence of single-vehicle accidents in SUVs by 63 percent.

Antilock Brake System (ABS) Operation

Wheel speed sensors are mounted at each wheel. In this ABS system, the wheel speed sensors are integral with the front or rear wheel bearing hubs. These wheel bearing hubs with the integral wheel speed sensors are non-serviceable (Figure 8-52). Each wheel speed sensor contains a toothed ring that rotates past a stationary electromagnetic wheel speed sensor. This sensor contains a coil of wire surrounding a permanent magnet. As the toothed ring rotates past the sensor, an alternating current (AC) voltage is produced in the sensor. This voltage signal from each wheel speed sensor is sent to the EBTCM. As wheel speed increases, the frequency of AC voltage produced by the wheel speed sensor increases proportionally. During a brake application, the wheels slow down, and the frequency of AC voltage in the wheel speed sensors also decreases. If a wheel is nearing a lockup condition during a hard brake application, the frequency of the AC voltage from that wheel speed sensor becomes very slow. The EBTCM detects impending wheel lockup from the frequency of AC voltage signals sent from the wheel speed sensors.

The brake pressure modulator valve (BPMV) contains a number of electrohydraulic valves. These valves are operated electrically by the EBTCM. These valves in the BPMV are connected hydraulically in the brake system. A **hold valve** and a **release valve** are connected in the brake line to each wheel (Figure 8-53). If a wheel speed sensor signal indicates an impending wheel lockup condition, the EBTCM energizes the normally open hold solenoid connected to the wheel that is about to lock up. This action closes the solenoid and isolates the wheel caliper from the master cylinder to prevent any further increase in brake pressure. If the wheel speed sensor signal still indicates an impending wheel lockup, the EBTCM keeps the hold solenoid closed and opens the normally closed release solenoid momentarily. This action reduces wheel caliper pressure to reduce brake application force and prevent wheel

A **hold valve** opens and closes the fluid passage to each wheel caliper.

When energized, a **release valve** reduces pressure in a wheel caliper.

FIGURE 8-52 **Wheel speed sensor.**

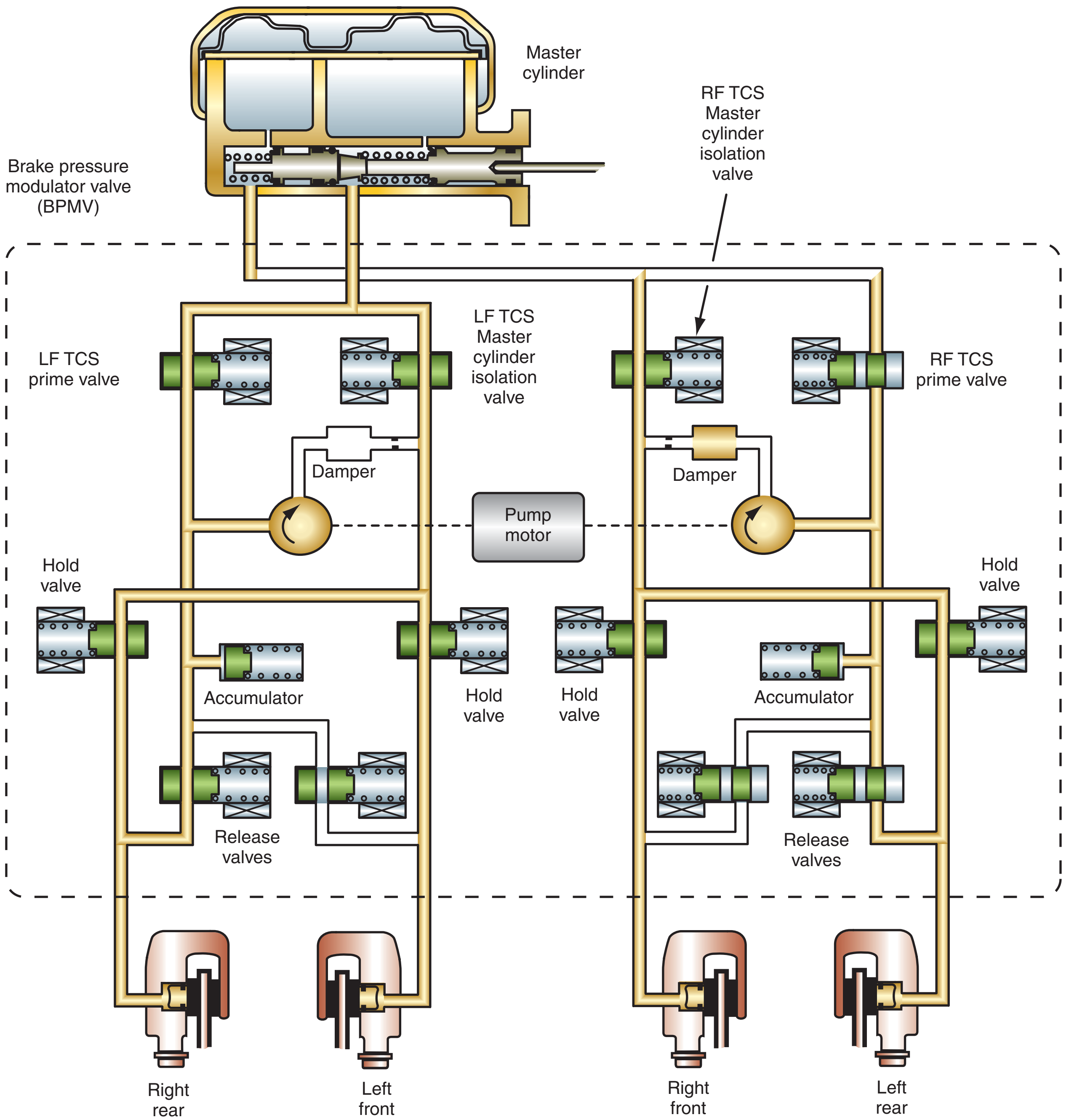


FIGURE 8-53 **Brake pressure modulator valve (BPMV).**

lockup. The EBTCM pulses the hold and the release solenoids on and off to supply maximum braking force without wheel lockup.

When the hold and the release valves are pulsated during a prolonged antilock brake function, the brake pedal fades downward as brake fluid flows from the release valves into the accumulators. To maintain brake pedal height during an antilock brake function, the EBTCM starts the pump in the BPMV at the beginning of an antilock function. When the pump motor is started, the pump supplies brake fluid pressure to the hold valves and wheel calipers. Pump motor pressure is also supplied back to the master cylinder. Under this condition, the driver may feel a firmer brake pedal and pedal pulsations and may hear the clicking action of the hold and the release solenoids.

ANTILOCK and BRAKE warning lights are mounted in the instrument panel. Both of these lights are illuminated for a few seconds after the engine starts. If the amber ANTILOCK light is on with the engine running, the EBTCM has detected an electrical fault in the ABS system. Under this condition, the EBTCM no longer provides an ABS function, but normal power-assisted brake operation is still available. When the red BRAKE warning light is illuminated with the engine running, the parking brake may be on, the master cylinder may be low on brake fluid, or there may be a fault in the ABS system.

Traction Control System (TCS) Operation

The EBTCM detects drive wheel spin by comparing the two drive wheel speed sensor signals. Wheel spin on both drive wheels is detected by comparing the wheel speed sensor signals on the drive wheels and non-drive wheels. If a wheel speed sensor signal informs the EBTCM that one or both drive wheels are spinning, the EBTCM enters the traction control mode. First, the EBTCM requests the PCM to reduce the amount of engine torque supplied to the drive wheels. The PCM reduces engine torque by retarding the ignition spark advance and shutting off the fuel injectors of a very short time. The PCM then sends a signal back to the EBTCM regarding the amount of torque delivered to the drive wheels. If one or both drive wheels continue to spin on the road surface, the EBTCM energizes the normally closed prime valve, closes the normally open isolation valve, and starts the pump in the BPMV. Under this condition, the prime valve opens and the pump begins to move brake fluid from the master cylinder through the prime valve to the pump inlet. The closed isolation valve prevents the pump pressure from being applied back to the master cylinder. Under this condition, the pump pressure is supplied through the normally open hold valve to the brake caliper on the spinning wheel. This action stops the wheel from spinning. If both drive wheels are spinning on the road surface, the EBTCM operates both prime valves and isolation valves to supply brake fluid pressure to both drive wheel brake calipers. During a TCS function, the EBTCM pulses the hold and the release solenoids on and off to control wheel caliper pressure. The EBTCM limits the traction control function to a short time period to prevent overheating brake components. During a TCS function, these messages may be displayed in the driver information center (DIC):

1. TRACTION ENGAGED is displayed after the TCS is in operation for 3 seconds.
2. TRACTION SUSPENDED is displayed if the EBTCM has discontinued the TCS function to prevent brake component overheating.
3. TRACTION OFF is displayed if the driver places the TCS switch on the instrument panel in the Off position.
4. TRACTION READY is displayed if the TCS switch is turned from Off to On.

During a TCS function, the EBTCM sends a signal through the data link to the powertrain control module (PCM). When this signal is received, the PCM disables some of the fuel injectors to reduce engine torque. This action also helps to prevent drive wheel spin. The PCM disables the two injectors at the beginning of the firing order and in the center of the firing order. Depending on the speed of drive wheel spin, the PCM may disable every second injector in the firing order. The injectors are disabled for a very short time period. The TCS system improves drive wheel traction, and this system also prevents the tendency for the vehicle to swerve sideways when one drive wheel is spinning. Therefore, the TCS system increases vehicle safety.

A **lateral accelerometer** supplies a voltage signal in relation to sideways movement of the chassis.

Yaw is erratic, side-to-side deviation from a course. The **yaw rate sensor** supplies a voltage signal in relation to rotational chassis speed during a sideways swerve.

Vehicle Stability Control

To provide stability control, the EBTCM uses two additional input signals from the **lateral accelerometer** and the **yaw rate sensor**. The lateral accelerometer is mounted under the front passenger's seat (Figure 8-54). The EBTCM sends a 5 V reference voltage to the lateral accelerometer. If the vehicle is driven straight ahead, the chassis has zero lateral acceleration.

FIGURE 8-54 **Lateral accelerometer.**

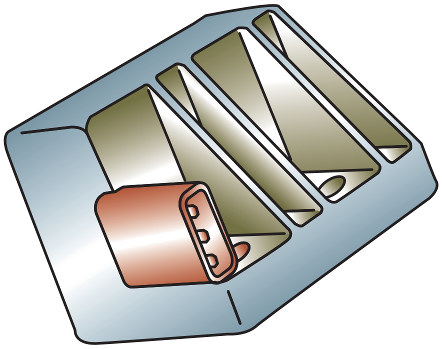


FIGURE 8-55 **Yaw rate sensor.**

Under this condition, the lateral accelerometer provides a 2.5 V signal to the EBTCM. If the vehicle begins to swerve sideways because of slippery road conditions, high-speed cornering, or erratic driving, the lateral accelerometer signal to the EBTCM varies from 0.25 V to 4.75 V, depending on the direction and severity of the swerving action.

The yaw rate sensor is mounted under the rear package shelf (Figure 8-55). Some yaw rate sensors contain a precision metal cylinder whose rim vibrates in elliptical shapes. The vibration and rotation of this metal cylinder is proportional to the rotational speed of the vehicle around the center of the cylinder. On some models the lateral accelerometer and yaw rate sensors are combined in a single sensor. The sensor mounting location varies depending on the vehicle make and model year.

The EBTCM sends a 5 V reference voltage to the yaw rate sensor. If the vehicle chassis experiences zero yaw rate, the yaw rate sensor sends a 2.5 V signal to the EBTCM module. If the vehicle begins to swerve sideways, the yaw rate sensor provides a 0.25 V to 4.75 V signal to the EBTCM, depending on the direction and severity of the swerve. The EBTCM also uses the wheel speed sensor signals for stability control. If the vehicle begins to swerve sideways, the EBTCM energizes the normally closed prime valve and closes the normally open isolation valve connected to the appropriate front wheel; then it starts the pump in the BPMV. Under this condition, the prime valve opens and the pump begins to move brake fluid from the master cylinder through the prime valve to the pump inlet. The closed isolation valve prevents the pump pressure from being applied back to the master cylinder. Under this condition, the pump pressure is supplied through the normally open hold valve to the brake caliper on the appropriate front wheel. Applying the brake on the front wheel pulls the vehicle out of the swerve and prevents the complete loss of steering control. If the EBTCM detects an electrical fault in the stability control system, STABILITY REDUCED is displayed in the DIC. If the EBTCM enters the stability control mode, STABILITY ENGAGED is indicated in the DIC.

In Figure 8-56, two vehicles driving side-by-side are negotiating a lane change to the left. The vehicle on the right has vehicle stability control, and the vehicle on the left does not have this system. As the vehicle on the left begins to turn, the rear of the vehicle begins to swing around. When the vehicle on the right starts to turn, the rear of the vehicle swerves slightly and the right front brake is applied by the vehicle stability control system to prevent this swerve. Further into the turn, the driver attempts to steer the car on the left, but this car enters into an uncontrolled swerve with loss of steering control. As the car on the right continues into the turn, the rear of the vehicle swerves slightly, but the vehicle stability control system again applies the right front brake momentarily to prevent this swerve. The car with the stability control system completes the turn while maintaining directional stability,

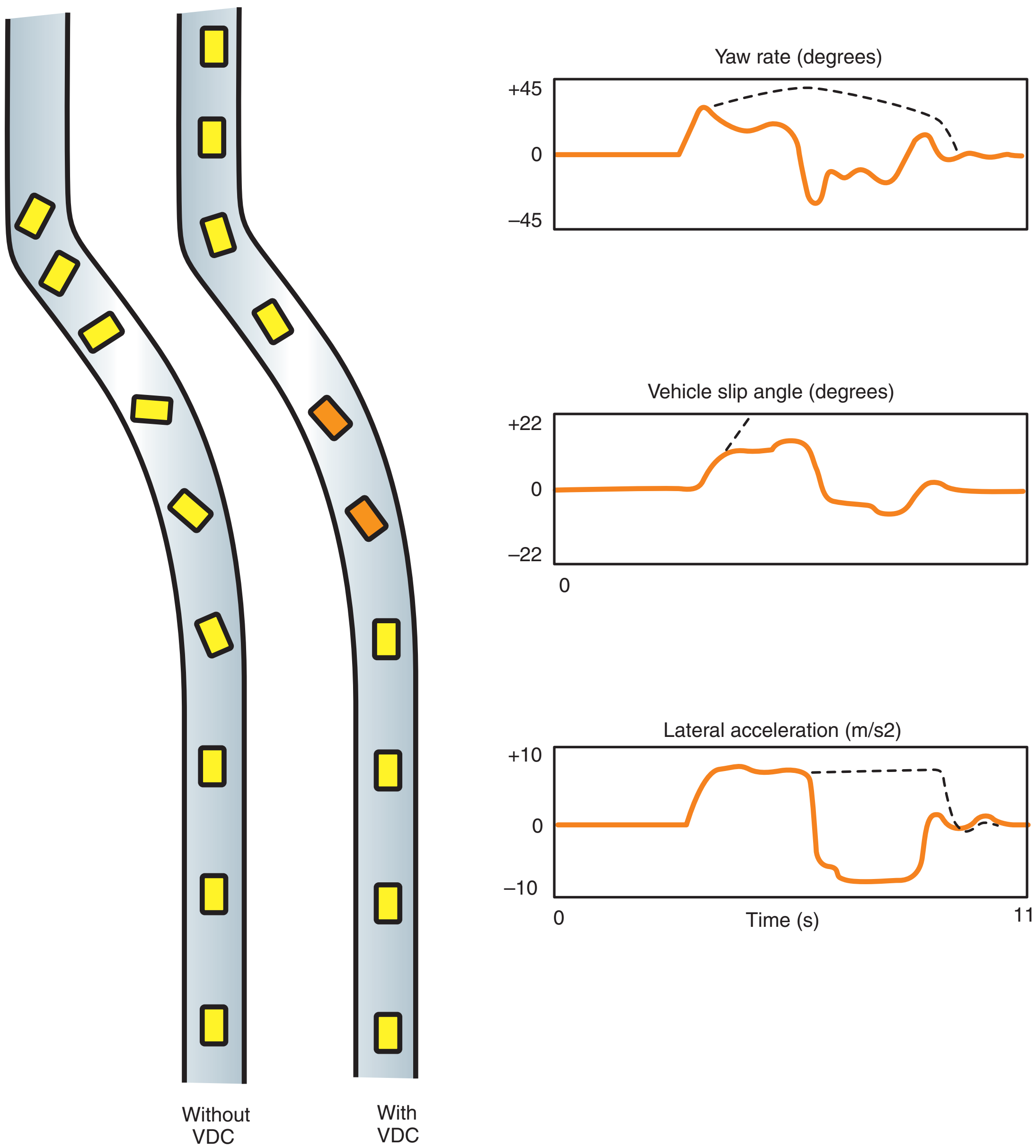


FIGURE 8-56 **Comparison during a turn between a vehicle with a stability control system and a vehicle with no stability control system.**

but the vehicle without stability control goes into an uncontrolled swerve with complete loss of directional control. The vehicle stability control system improves vehicle safety! The other charts in Figure 8-56 indicate that yaw rate, vehicle slip angle, and lateral acceleration are greatly reduced on a vehicle with a stability control system.

Active Roll Control Systems

Two independent automotive component manufacturers have developed active roll control systems in response to concerns about sport utility vehicles (SUVs) that roll over more easily compared with cars because of the SUVs' higher center of gravity. The active roll control systems were developed in response to this concern. The active roll control system contains a control module, accelerometer, speed sensor, fluid reservoir, electrohydraulic pump, pressure control valve, directional control valve, and a hydraulic actuator in both the front and rear stabilizer bars (Figure 8-57). The accelerometer and speed sensor may be common to systems

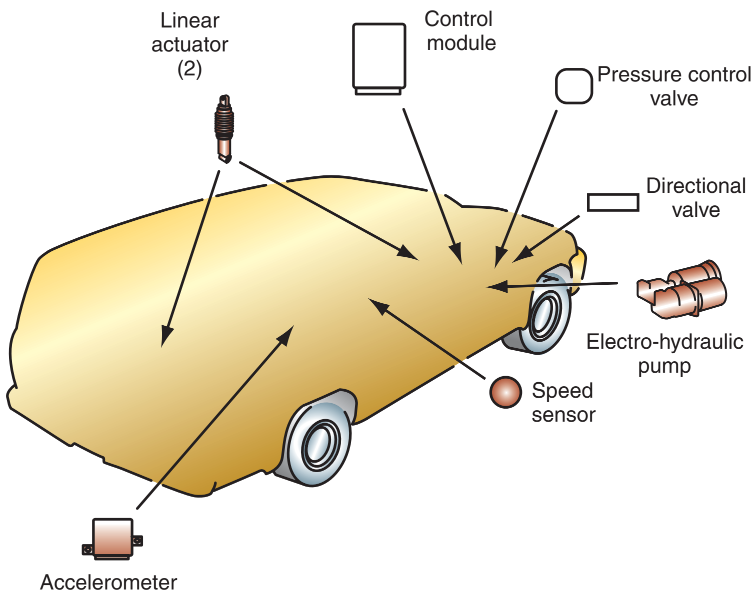


FIGURE 8-57 **Active roll control system components.**

other than the active roll control. The electrohydraulic pump may also be used as the power steering pump. The active roll control system may be called a roll stability control (RSC) system or a dynamic handling system (DHS). Some active roll control systems have a gyro sensor that provides a voltage signal to the control module in relation to the vehicle roll speed and angle.

When the vehicle is driven straight ahead, the active roll control system does not supply any hydraulic pressure to the linear actuators in the stabilizer bars. Under this condition, both stabilizer bars move freely until the linear actuators are fully compressed. This action provides improved individual wheel bump performance and better ride quality. If the chassis begins to lean while cornering, the module operates the directional valve so it supplies fluid pressure to the linear actuators in the stabilizer bars. This action stiffens the stabilizer bar and reduces body lean (Figure 8-58). The active roll control system increases safety by reducing body lean, which decreases the possibility of a vehicle rollover.

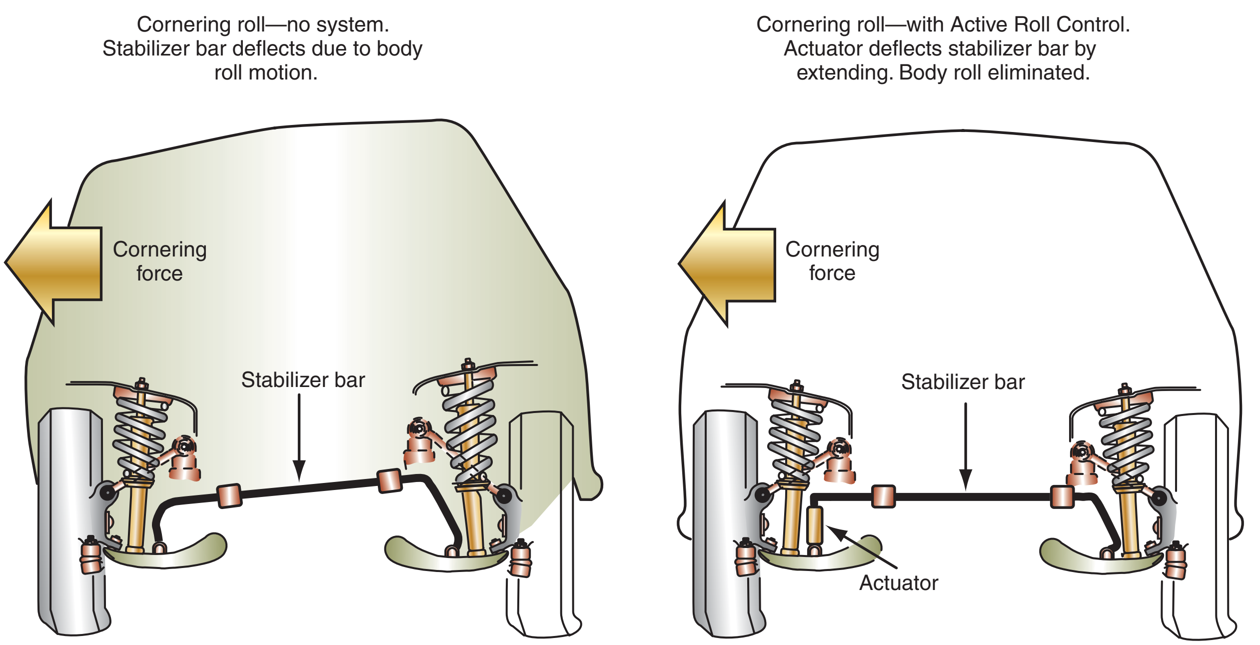


FIGURE 8-58 **Active roll control system operation while cornering.**

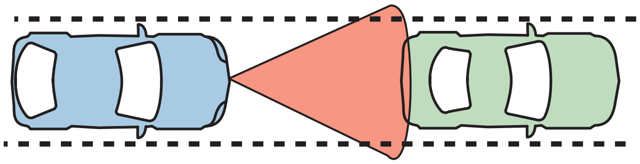


FIGURE 8-59 **The radar sensor measures the distance to the vehicle in front and the relative speed of this vehicle.**

One vehicle manufacturer has chosen to reduce the yaw force on a new model by reducing the weight at the front and rear of the vehicle, and shifting the weight toward the midpoint on the car. This was accomplished by manufacturing the hood, trunk lid, and bumper beams from aluminum. Engine weight was reduced by installing hollow camshafts, and using a lighter weight block and cylinder heads. These changes reduced the weight of the vehicle by 180 lbs. (80 kg), which reduced the yaw force and also improved fuel economy and performance.

Adaptive Cruise Control (ACC) Systems

Adaptive cruise control (ACC) is available on some current vehicles. The ACC system has a long-range radar sensor mounted behind the front bumper. This radar sensor sends signals to the ACC computer. The ACC computer uses the vehicle network to remain in constant contact with the PCM and ABS computers. The ACC system measures the distance to the vehicle in front and the relative speed of that vehicle (Figure 8-59). The ACC system can detect objects more than 330 ft (100 m) ahead of the vehicle. A dash control allows the driver to set the distance between the vehicle and the vehicle ahead.

If the ACC system detects a slower moving vehicle ahead and the distance to that vehicle becomes less than the driver-adjusted setting, the ACC system uses the throttle control and limited brake application with a 0.3 g braking force to slow down the vehicle. When this action is taken, a small green car icon is illuminated in the head up display (HUD). If the distance to the vehicle in front is still decreasing after this action is taken, the icon in the HUD turns from green to yellow. When the ACC system senses that a collision is imminent, a large red car icon with yellow flashes is illuminated in the HUD and the ACC system activates a beeper.

When the lane ahead of the vehicle is clear, the ACC system maintains the cruising speed set by the driver. The ACC system can detect another vehicle crossing from an adjacent lane into the lane in front of the vehicle and take appropriate action if there is not sufficient distance between the two vehicles. The radar signals in the ACC system provide excellent performance even in adverse weather conditions.

Lane Departure Warning (LDW) Systems

Some current vehicles are equipped with **lane departure warning** (LDW) systems. The LDW system has a video camera mounted behind the rear view mirror (Figure 8-60). This camera uses software to monitor highway lane markings (Figure 8-61). The camera measures the distance from the vehicle to the lane markings and the lateral velocity of the vehicle in relation to the lane markings to determine if the vehicle is moving out of the lane. Signals

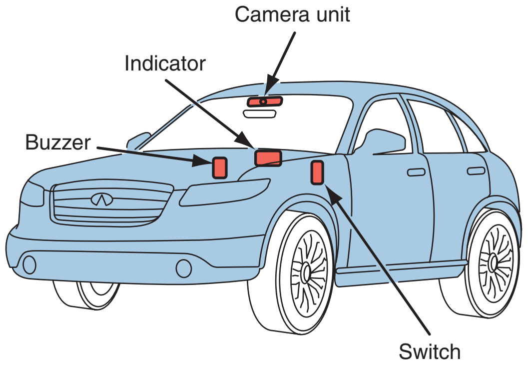


FIGURE 8-60 **Components in the lane departure warning (LDW) system.**

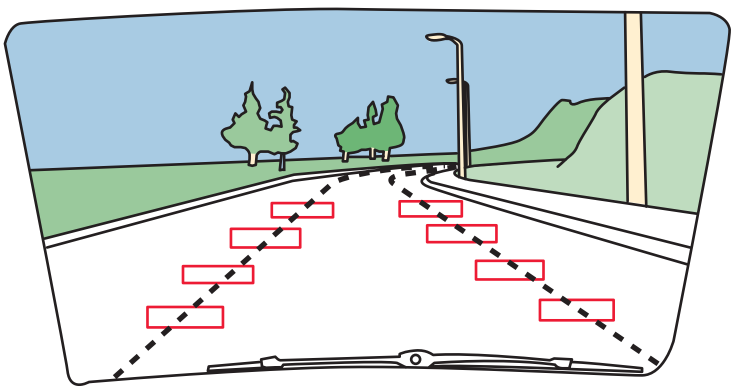


FIGURE 8-61 **The LDW camera measures the distance from vehicle to the highway lane markings.**

from the camera are sent to the LDW module. The VSS is also sent to the LDW module. The LDW system does not operate below 45 mph (72 km/h). If the vehicle speed is above 45 mph (72 km/h) and the camera signal indicates the vehicle is moving out of the lane, the LDW module operates a buzzer and an indicator warning in the instrument panel. Activation of the turn signals temporarily disables the LDW system to prevent incorrect LDW warnings.

Some LDW systems have lane-departure prevention capabilities. If the vehicle is moving toward the lane markings on the left, the ABS and stability control computer lightly pulse the brakes on the right side of the vehicle. When the wheels on the right side slow down, the wheels on the left side turn faster than the wheels on the right side, and this action steers the car away from the highway markers on the left. Other LDW systems activate the electronic steering on the vehicle to steer the vehicle away from the lane markers if a lane departure is starting to occur. A dash switch allows the driver to turn the LDW system on or off.

AUTHOR'S NOTE: Statistics compiled by one of the major car manufacturers indicate that 30 percent of all vehicle accidents in the United States involve rear-end collisions. In half of these collisions, the driver did not apply the brakes before collision occurred. The statistics also indicate that 75 percent of these rear-end collisions occur below 19 mph (30 km/h).

Collision Mitigation Systems

Some vehicles are equipped with a collision mitigation system that uses radar and camera information to detect a vehicle in front. The collision mitigation computer is in constant communication with the PCM and ABS computers via the vehicle network. If the radar and camera signals indicate a vehicle in front is too close and a collision is imminent, the collision mitigation computer warns the driver with a visual and audible warning. If the driver does not apply the brakes, the collision mitigation computer applies the brakes aggressively with a 0.5 g force to slow down the vehicle. The vehicle manufacturer's information indicates that the collision mitigation system will avoid rear-end collisions up to 9 mph (19 km/h) and mitigate the effects of a collision up to 19 mph (30 km/h). On some vehicles, the collision mitigation system is called a **City Safety System**.

Telematics

The use of telematics is expected to increase significantly in the next few years. Vehicle manufacturers and electronic communications companies have not decided the exact information that will be transmitted to vehicles through telematics, but the following are some possible options.

Vehicle manufacturers could use telematics to inform vehicle owners when their vehicles require specific service. This is being done presently to some extent by General Motors through their OnStar system. Telematics could be used for emission testing. At present, 33 states in the United States have emission test centers, and vehicles must be taken to these centers for emission testing at specific intervals. Using telematics, the emission test center could monitor the vehicle emission levels, and if the emission standards are exceeded, the test center could inform the vehicle owner/driver that the vehicle must be taken to a certified repair center for emission service.

Telematics may also be used to improve vehicle safety. At present, a Vehicle Infrastructure and Integration (VII) system has installed two test projects, one in California and another one in the Detroit area. In these test projects, roadside beacons communicate with vehicle networks. In each project, approximately 25 vehicles supplied by car manufacturers are driven on a 75-mile (120 km) stretch of highway where the communications beacons are installed. At hidden intersections, monitoring stations inform the test vehicles that vehicles are approaching the intersection. Other inputs inform the test vehicles regarding heavy traffic congestion or black ice.

Telematics may be defined as wireless communication between the telephone system and vehicle networks

AUTHOR'S NOTE: The following are some interesting facts about the Onstar communications system:

1. OnStar is a factory-installed option on General Motors vehicles. One-year OnStar service is included in the new GM vehicle purchase. Today there are approximately 5 million OnStar subscribers, and the subscriber list is expected to double by 2011.
2. A sophisticated module in each vehicle allows communication between the vehicle and an OnStar center at the push of a button in the vehicle. This communication is enabled by the vehicle battery and a special external antenna on each vehicle that combine cell reception, global positioning system (GPS), and XM satellite radio to provide range and performance that far exceed handheld cell phones and GPS devices.
3. Approximately 3,000 advisors work at three Onstar call centers and receive up to 100,000 calls in three languages on a busy day. At the beginning of an OnStar call, the driver must select the English, Spanish, or French language option, and a special routing system directs the call to an advisor speaking the selected language.
4. Ninety-five percent of emergency calls are answered in 5 seconds. The OnStar module on the vehicle notifies a center if the air bags deploy. An advisor calls the vehicle in an attempt to contact the driver or vehicle occupants. If the advisor cannot contact the driver or occupants, the advisor notifies emergency response personnel regarding the vehicle location. The OnStar system handles approximately 2,200 vehicle crash responses per month.
5. The OnStar system processes about 600,000 requests for driving directions each month. OnStar subscribers purchase approximately 31 million minutes of OnStar time per month.
6. Current OnStar modules are connected to the CAN data network on the vehicle. This connection allows the OnStar module to monitor the powertrain, ABS, traction control, and air bag systems. On current vehicles, the OnStar module can read about 1600 DTCs and monitor the engine oil life, emission levels, and tire pressure. About 3 million OnStar subscribers have signed up for a monthly vehicle condition report that informs the subscriber regarding vehicle defects in any of the monitored systems. The monthly vehicle condition report also informs the subscriber regarding any recall repairs that have not been completed on their vehicle. Approximately, 61,000 calls are processed monthly for instant remote diagnosis.

INTERESTING FACT

Each year in the United States, approximately 43,000 deaths are caused by traffic accidents. This is approximately the equivalent of a 747 aircraft crashing each week.

7. If an OnStar subscriber is locked out of one's vehicle, he or she can phone an OnStar advisor and provide his or her OnStar number. The advisor can then unlock the doors on the subscriber's vehicle. If an OnStar advisor is informed that a vehicle is stolen, the advisor can use GPS to provide the vehicle location. Select 2009 General Motors vehicles have OnStar's Stolen Vehicle Slowdown service. If police are following a stolen vehicle, they can inform an OnStar advisor and request that the vehicle be stopped. The advisor will flash the vehicles external lights without the driver's awareness. When police confirm that the vehicle lights have flashed, the OnStar advisor will send a signal to the stolen vehicle that causes the electronic throttle control to remain continually in the idle position. All other vehicle functions such as steering and brakes operate normally. The OnStar subscriber cannot request that the vehicle be stopped. At present, OnStar receives about 700 stolen vehicle calls per month. It is estimated that each year there are 30,000 high-speed chases in the United States each year, and 25 percent of these end in injury, and 300 deaths are a result of these chases.
8. The first OnStar expansion outside of North America is scheduled for 2009 in China, using the Mandarin language.

Summary

- In a PRC system, the steering sensor informs the control module regarding the amount and speed of steering wheel rotation.
- The PRC system switches from the normal to the firm mode during high-speed operation, braking, hard cornering, and fast acceleration.
- The struts and shock absorbers in some PRC systems provide three times as much damping action in the firm mode as in the normal mode.
- The accelerometer in a CCR system contains a mercury switch and this accelerometer sends a vehicle acceleration signal to the control module.
- In a CCR system, the accelerometer signal or the vehicle speed signal may inform the control module to switch from the normal to the firm mode.
- An electronic air suspension system maintains a constant vehicle trim height regardless of passenger or cargo load.
- To exhaust air from an air spring, the air spring solenoid valve and the vent valve in the compressor head must be energized.
- To force air into an air spring, the compressor must be running and the air spring solenoid valve must be energized.
- The air spring valves are retained in the air spring caps with a two-stage rotating action much like a radiator cap.
- An air spring valve must never be loosened until the air is exhausted from the spring.
- Voltage is supplied through the compressor relay points to the compressor motor. This relay winding is grounded by the control module to close the relay points.
- The On/Off switch in an electronic air suspension system supplies 12 V to the control module. This switch must be off before the car is hoisted, jacked, towed, or raised off the ground.
- If a car door is open, the control module does not respond to lower vehicle commands in an electronic air suspension system.
- When the brake pedal is applied and the doors are closed in an electronic air suspension system, the control module ignores all requests from the height sensors.
- In an electronic air suspension system, if the doors are closed and the brake pedal is released, all requests to the control module are serviced by a 45-second averaging method.

Terms to Know

Accelerometer
Actuator
Adaptive cruise control system
Air spring solenoid valve
Air springs
Antilock brake system (ABS)
Automatic level control (ALC)
Brake pressure modulator valve (BPMV)
Brake pressure switch
City safety system
Collision mitigation system
Cross-axis ball joints
Damper solenoid valve
Electronic brake and traction control module (EBTCM)
Electronic rotary height sensors
Electronic suspension control (ESC) system
Firm relay
Hall element
Height sensors

Summary

- If the control module in an electronic air suspension system cannot complete a request from a height sensor in three minutes, the control module illuminates the suspension warning lamp.
- In an automatic air suspension system, the control module controls suspension height and strut damping automatically without any driver controlled inputs.
- Rotary height sensors in automatic air suspension systems contain Hall elements. These sensors send voltage signals to the control module in relation to the amount and speed of wheel jounce and rebound.
- Some air suspension systems reduce trim height at speeds above 65 mph (105 km/h) to improve handling and fuel economy.
- The air suspension system on some four-wheel-drive vehicles increase suspension ride height when the driver selects four-wheel-drive high or four-wheel-drive low.
- The air suspension system on some four-wheel-drive vehicles have the capability to provide firmer shock absorber valving in relation to transfer case mode selection, vehicle speed, and operating conditions.
- The electronic suspension control system changes shock and strut damping forces in 10 to 12 milliseconds.
- In the electronic suspension control system, the module controls suspension damping, rear electronic level control, and speed sensitive steering automatically without any driver-operated inputs.
- A vehicle stability control system applies one of the front brakes if the rear of the car begins to swerve out of control. This action maintains vehicle direction control.
- An adaptive cruise control (ACC) system applies the vehicle brakes lightly and warns the driver if the system senses inadequate distance to the vehicle in front.
- A lane departure warning (LDW) system warns the driver if the vehicle begins to leave the current lane. Some LDW systems apply the vehicle brakes on one side or steers the vehicle back into the current lane when lane departure begins to occur.
- A collision mitigation system warns the driver and applies the vehicle brakes aggressively if a rear-end collision is about to occur with the vehicle in front.

Review Questions

Short Answer Essays

1. Describe the operation of the steering sensor in a PRC system.
2. Describe the purpose of the vehicle speed sensor signal in a PRC system.
3. Explain how air is forced into an air spring in a rear load-leveling air suspension system.
4. Describe the action taken by the control module if the control module in an electronic air suspension system receives a lower vehicle command from a rear suspension sensor with the doors closed, the brake pedal released, and the vehicle traveling at 60 mph (100 km/h).
5. Describe the action taken by the control module if the engine is running with a door open, and the control module receives a lower vehicle command from the height sensor in a rear load-leveling air suspension system.
6. List the conditions when the On/Off switch in an electronic air suspension system must be turned off.
7. Describe the conditions required for the control module to turn on the suspension warning lamp continually with the engine running in an electronic air suspension system.
8. Explain why the control module in an electronic air suspension system services

Terms to Know

(continued)

Hold valve
Lane departure warning (LDW) system
Lateral accelerometer
Lift/dive input
Light-emitting diodes (LEDs)
Lower vehicle command
MagneRide system
MR fluid
Network
Photo diodes
Programmed ride control (PRC) system
Pulse width modulation (PWM)
Raise vehicle command
Release valve
Soft relay
Speed sensitive steering (SSS) system
Stabilitrak®
Steering sensor
Steering wheel position sensor (SWPS)
Telemotics
Throttle position sensor (TPS)
Traction control system (TCS)
Trim height
Vehicle dynamic suspension (VDS)
Vehicle speed sensor (VSS)
Vehicle stability control system
Vent valve
Wheel position sensor
Wheel speed sensors
Yaw rate sensor

all commands by a 45-second averaging method when the doors are closed and the brake pedal is released.

9. Explain why the suspension warning lamp in an electronic air suspension system may not indicate a defect immediately when the engine is started.
10. Explain how a vent solenoid is damaged by reversed battery polarity in a rear load-leveling air suspension system.

Fill-in-the-Blanks

1. The armature response time is _______________ milliseconds in a PRC system strut.
2. In a PRC system, if the car is accelerating with the throttle wide open, the PRC system is in the _______________ mode.
3. When the PRC mode switch is in the Auto position, the control module changes to the firm mode if lateral acceleration exceeds _______________.
4. In a PRC system, lateral vehicle acceleration is sensed from the _______________ sensor.
5. In a rear load-leveling air suspension system, the control module energizes the compressor relay when a _______________ command is received.
6. Two height sensors are mounted on the ___________ suspension in an electronic air suspension system.
7. In an electronic air suspension system two hours after the ignition switch is turned off, ______________ _______________commands are completed, but _______________ _______________commands are ignored.
8. In a rear load-leveling air suspension system, if the On/Off switch in the trunk is off, the system is _______________.
9. An electronic rotary height sensor contains a _______________ _______________.
10. In a continuously variable road sensing suspension system, the module senses vehicle lift and dive from some of the _______________ _______________ _______________ inputs.

Multiple Choice

1. While discussing a programmed ride control (PRC) system:
   A. The brake system pressure must be 300 psi (2,068 kPa) before this mode change occurs.
   B. A PRC system switches from the auto mode to firm mode if the vehicle accelerates with 90 percent throttle opening.
   C. The PRC system switches to the firm mode if lateral acceleration exceeds 0.25 g.
   D. The mode indicator light in the tachometer is illuminated in the plush ride mode.
2. To increase the rear trim height in an electronic air suspension system, the control module:
   A. Starts the compressor and opens the vent valve.
   B. Starts the compressor and closes the rear air spring valves.
   C. Stops the compressor and opens the rear air spring valves.
   D. Starts the compressor and opens the rear air spring valves.
3. All these statements about air springs, shock absorbers, and struts are true EXCEPT:
   A. Air springs can be mounted separately from the shock absorbers.
   B. Air springs can be mounted over the front and rear struts.
   C. Some struts contain a solenoid actuator that controls strut firmness.
   D. Some air suspension systems have seven driver selectable operating modes.
4. The magneto-rheological fluid in the shock absorbers or struts in an ESC system contains:
   A. Automatic transmission fluid.
   B. Suspended iron particles.
   C. Power steering fluid.
   D. 5W-30 engine oil.
5. To sense the distance to the vehicle in front, an adaptive cruise control system uses:
   A. A video camera.
   B. A short-range radar signal.
   C. A digital camera.
   D. A Long-range radar signal.

6. In an ESC system with magneto-rheological fluid in the shock absorbers or struts, the control module can vary the shock absorber firmness in:

A. 1 millisecond.

B. 5 milliseconds.

C. 10 milliseconds.

D. 152 milliseconds.

7. All of these statements about network systems are true EXCEPT:

A. A network system can be a single-wire or dual-wire system.

B. Some network systems operate between 0 V and 12 V.

C. Some vehicles have two network systems.

D. A fiber-optic network system has a very high data transmission rate.

8. In some traction control systems if the control module senses drive wheel spin, the first action taken by the control module is to:

A. Retard the spark advance and shut off the fuel injectors.

B. Apply the brakes on both non-drive wheels.

C. Apply the brake on the spinning drive wheel.

D. Apply the brake on the non-spinning drive wheel.

9. On a vehicle with a stability control system, if icy road conditions cause the vehicle to begin swerving sideways, the stability control module:

A. Applies the brakes on both rear wheels.

B. Applies the brakes on both front wheels.

C. Applies the brake on one front wheel.

D. Applies the brake on one front wheel and the opposite rear wheel.

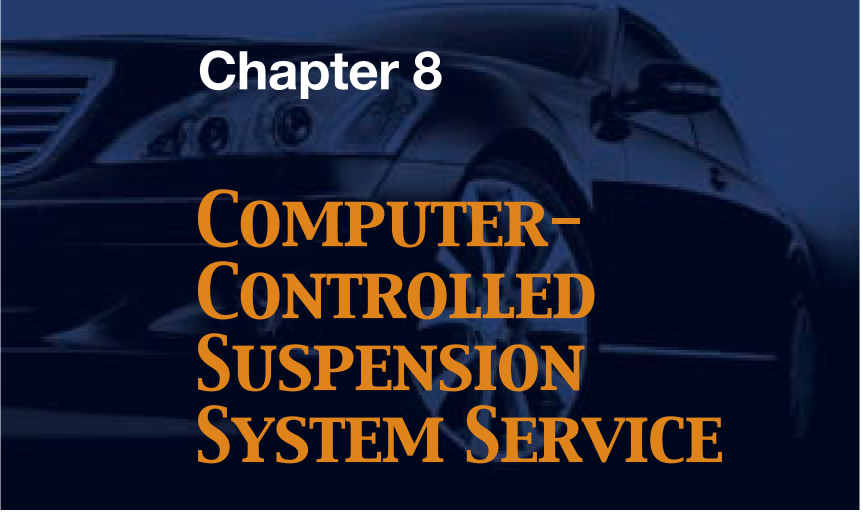
10. All of these statements about a rear load-leveling suspension system are true EXCEPT:

A. The On/Off switch is mounted in the vehicle trunk.

B. The control module operates the compressor relay.

C. If a door is open, the control module completes the lower suspension height commands.

D. The rear suspension has one, non-serviceable suspension height sensor.



Chapter 8

Computer-Controlled Suspension System Service

Upon completion and review of this chapter, you should be able to:

- Diagnose programmed ride control (PRC) systems.
- Diagnose electronic air suspension systems.
- Remove, replace, and inflate air springs.
- Adjust front and rear trim height onelectronic air suspension systems.
- Service and repair nylon air lines.
- Diagnose vehicle dynamic suspension (VDS) systems.
- Remove and replace air springs on VDS systems.
- Perform an on-demand self-test on VDS systems.
- Diagnose electronic suspension control (ESC) systems.
- Display and interpret scan tool data on ESC systems.
- Use the output controls function to diagnose ESC systems.
- Diagnose vehicle networks.

Each year more vehicles are equipped with computer-controlled suspension systems, and these systems are becoming increasingly complex. Therefore, technicians must understand the correct procedures for diagnosing and servicing these systems. When a technician understands computer-controlled suspension systems and the proper diagnostic procedures for these systems, diagnosis becomes faster and more accurate.

BASIC TOOLS

Basic technician's tool set

Service manual

Floor jack

Safety stands

Utility knife

Machinist's ruler or tape measure

Preliminary Inspection of Computer-Controlled Suspension Systems

Prior to diagnosing a computer-controlled suspension system, a preliminary inspection should be performed. The preliminary inspection may locate a minor defect that is the cause of the problem. If the preliminary inspection is not performed, a lot of time may be wasted performing advanced diagnosis when the problem is a minor defect. When the preliminary diagnosis does not locate any minor problems, further diagnosis is required.

Follow these steps to complete the preliminary diagnosis:

1. Talk to the customer and find out the exact complaint regarding vehicle operation.
2. If necessary, road test the vehicle to determine the exact symptoms.
3. Inspect the vehicle for any work that was completed recently, including body work. Wires or air lines may have been damaged by a collision.
4. Check all electrical connections and wiring in the computer-controlled suspension system.

5. If the vehicle has a computer-controlled air suspension system, listen for air leaks in the system.
6. If the vehicle has a computer-controlled air suspension system, check all the air lines for cracks, breaks, damage, and kinks.
7. Measure the vehicle curb (trim) height.
8. Check the operation of the suspension warning light or observe the message center in the instrument panel for displayed suspension messages.

Programmed Ride Control System Diagnosis

General Diagnosis

The **programmed ride control (PRC)** module monitors the complete system while the vehicle is driven. If a defect occurs in the PRC system, the mode indicator light starts flashing. When the mode selector switch is moved to the opposite position and returned to the same position, erroneous codes are cleared from the control module memory. If the mode indicator light continues flashing, the self-test should be performed.

Self-Test

The self-test connector is located under the ash tray (Figure 8-1). This connector has two terminals that must be connected during the self-test. A jumper tool should be fabricated to connect these terminals, and this tool should be soldered to the end of a 7-inch slotted screwdriver blade to access the self-test terminals (Figure 8-2).

Follow this procedure to perform the self-test:

1. Turn the ignition switch off and be sure the headlights and parking lights are off. These lights must remain off during the self-test.
2. Position the mode select switch in the Auto position.
3. Remove the ash tray and insert the fabricated tool in the self-test connector terminals.

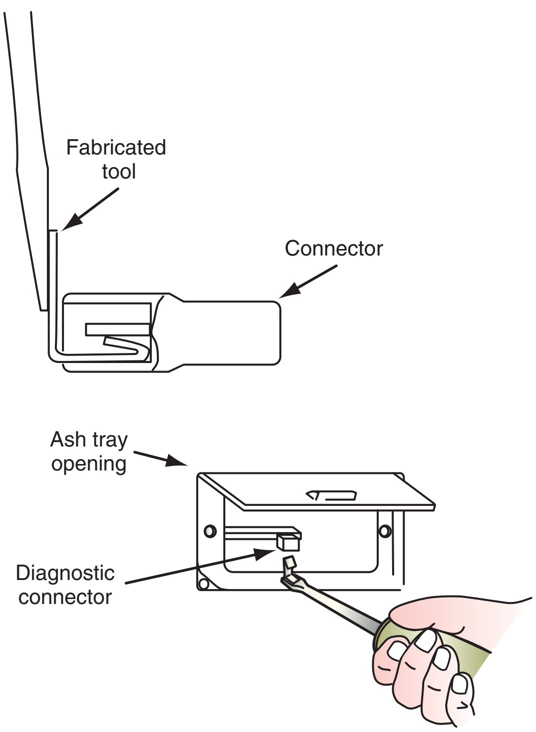


FIGURE 8-1 **Self-test terminals, programmed ride control system.**

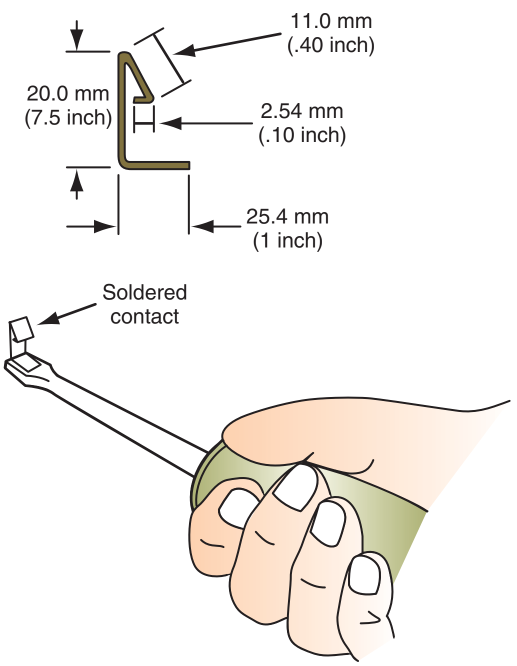


FIGURE 8-2 **Fabricated tool to connect the self-test terminals.**

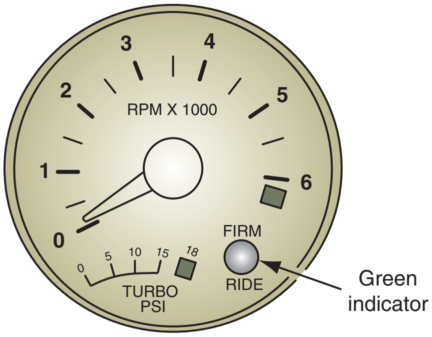


FIGURE 8-3 **Mode indicator in tachometer flashes trouble codes.**

PRC System Diagnostic Trouble Codes (DTCs)

Code	Defect
6	No problem
1	Left rear actuator circuit
2	Right rear actuator circuit
3	Right front actuator circuit
4	Left front actuator circuit
5	Soft relay control circuit shorted
7	PRC control module
13	Firm relay control circuit shorted
14	Relay control circuit

FIGURE 8-4 **PRC system diagnostic trouble codes (DTCs).**

4. Start the engine and leave the mode select switch in the Auto position.
5. When the engine has been running for 20 seconds or more, remove the tool from the self-test connector.
6. Count the mode indicator light flashes to obtain the trouble codes. For example, if the light flashes six times, code 6 has been provided. The light flashes each code four times at nine-second intervals. The mode indicator light is in the tachometer (Figure 8-3).

Diagnostic Trouble Codes (DTCs)

Several DTCs are available on the PRC system (Figure 8-4). The DTCs vary depending on the vehicle make and year. Always use the DTC list in the manufacturer's service manual. A trouble code indicates a defect in a specific area. For example, if DTC 2 is received, the defect may be in the right rear actuator or in the connecting wires.

After a PRC system defect has been corrected, the DTCs should be cleared. The system should be checked for DTCs again to make sure there are no other faults in the system.

SERVICE TIP:
Diagnostic trouble codes (DTCs) together with the vehicle manu facturer's service manual diagnostic procedures will usually locate the problem in a PRC system.

Electronic Air Suspension Diagnosis and Service

Air Spring Removal and Installation

WARNING: The system control switch must be in the Off position when system components are serviced to prevent personal injury and damage to system components.

WARNING: The system control switch must be turned off prior to hoisting, jacking, or towing the vehicle. If the front of the chassis is lifted with a bumper jack, the rear suspension moves downward. The electronic air suspension system will attempt to restore the rear trim height to normal, and this action may cause the front of the chassis to fall off the bumper jack, resulting in personal injury or vehicle damage.

WARNING: When air spring valves are being removed, always rotate the valve to the first stage until all the air escapes from the air spring. Never turn the valve to the second (release) stage until all the air is released from the spring. If this action is taken, the valve may be blown out of the air spring with considerable force, and this may cause personal injury.

Diagnostic trouble codes (DTCs) indicate defects in specific areas of computer-controlled systems.

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WARNING: When removing and replacing many suspension components such as lower control arms in an air spring suspension system, air must be exhausted from the air spring to relieve tension on the components before the removal procedure. Failure to observe this precaution may result in personal injury.

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Many components in an electronic air suspension system, such as control arms, shock absorbers, and stabilizer bars, are diagnosed and serviced in the same way as the components in a conventional suspension system. However, the air spring service procedures are different compared to coil-spring service procedures on a conventional suspension system.

The air spring removal and replacement procedure varies depending on the vehicle make and model year. For example, a different air spring removal and replacement procedure is required on vehicles with integral air springs and struts, and vehicles with the air springs mounted separately from the shock absorbers. Front and rear air spring removal and replacement procedures may vary. Always follow the exact air spring removal and replacement procedure in the vehicle manufacturer's service manual. The following is a typical air spring removal and replacement procedure for some vehicles with the air springs mounted separately from the shock absorbers:

Follow these steps for air spring removal:

1. Turn off the electronic air suspension switch in the trunk.
2. Hoist the vehicle and allow the suspension to drop downward, or lift the vehicle with a floor jack and place safety stands under the chassis. Lower the vehicle onto the safety stands and allow the suspension to drop downward.
3. Disconnect the nylon air line from the spring solenoid valve, and rotate the valve to the first stage to allow the air to escape from the spring. Never turn the valve to the second stage until all the air is exhausted from the spring.
4. Disconnect the lower spring retainer and remove the spring from the chassis.
5. Before an air spring is installed, it must be properly folded over the piston at the bottom of the membrane (Figure 8-5).
6. Install the spring in the chassis and connect the lower spring retainer. Be sure the top of the spring is properly seated in the spring seat. When an air spring is installed in the front or rear suspension, the spring must be properly positioned to eliminate folds and creases in the membrane (Figure 8-6)

Removal and Replacement of Air Springs with Integral Struts

Front or rear air springs with integral struts are sold only as an assembly. Do not attempt to service these components. The following is typical front air spring removal and replacement procedure on an automatic air suspension system with air springs containing integral struts:

1. Turn off the air suspension switch.
2. Raise the vehicle on a frame-contact lift and allow the suspension to drop downward.
3. Remove the wheel and tire assembly on the corner of the vehicle that requires air spring and strut removal.
4. Release the metal clip at the top height sensor mount, then remove the height sensor off the ball stud.
5. Remove the air spring solenoid retainer, loosen the air spring solenoid valve to the first position, and allow all the air pressure to be relieved from the air spring.

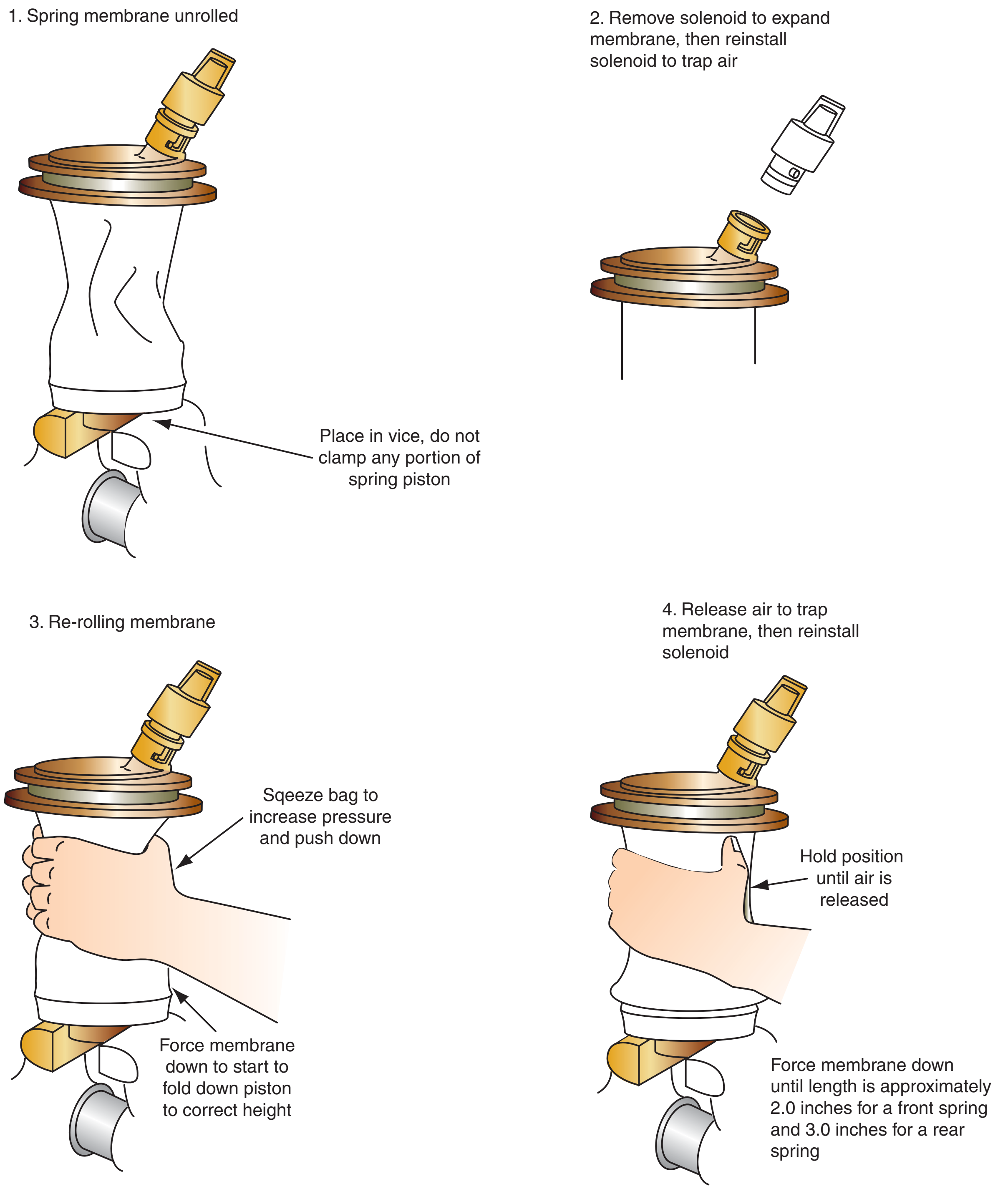


FIGURE 8-5 **Air spring folding.**

6. Push the air solenoid line retainer toward the center of the solenoid, and pull the rubber hose and nylon tube out of the solenoid (Figure 8-7). Remove the electrical connector from the solenoid.
7. Remove the air spring solenoid valve.
8. Remove the top strut cover, and remove three strut-to-strut tower retaining nuts (Figure 8-8).
9. Remove the strut-to-suspension arm retaining nut and bolt.
10. Remove the strut and spring assembly from the vehicle.

CAUTION:
Loosening the large center nut on the top of the strut rod may cause a permanent leak through the top of the air spring.

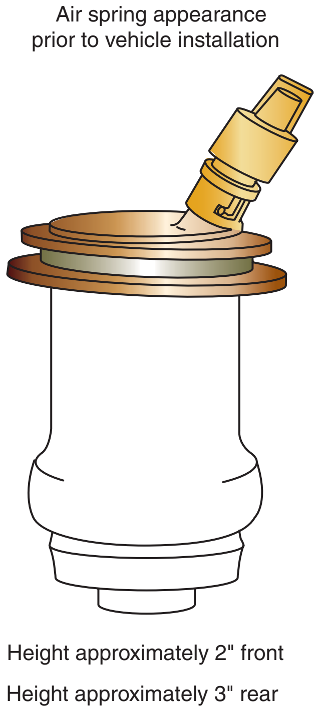


FIGURE 8-6 **When an air spring is installed in the front or rear suspension, the spring must be properly positioned to eliminate folds and creases in the membrane.**

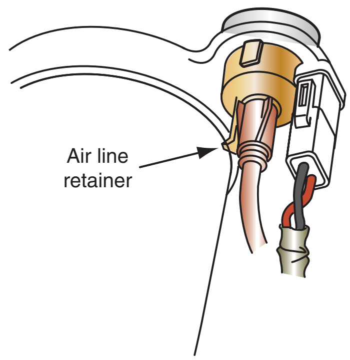


FIGURE 8-7 **Air line removal from the air spring solenoid valve.**

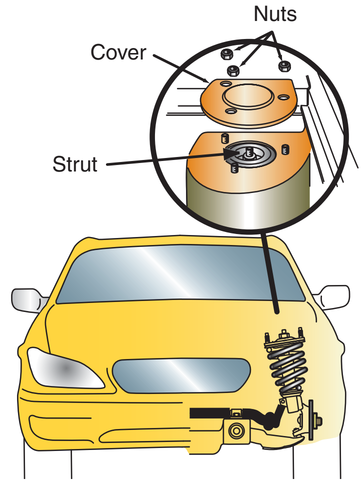


FIGURE 8-8 **Removing the upper strut mount retaining nuts.**

Follow these steps to install a replacement front air spring and integral strut:

1. Install the air spring and strut assembly into the front suspension until the upper strut mount retaining bolts extend through the bolt holes in the strut tower.
2. Install the upper strut mount retaining nuts and tighten these nuts to the specified torque.
3. Install the lower strut-to-suspension retaining bolt and nut, and tighten the nut until it is snug. The nut on this bolt must be tightened to the specified torque after the vehicle weight is applied to the suspension.
4. Install the air spring solenoid valve fully into the air spring, and install the valve retainer.
5. Install the air line and electrical connector into the solenoid valve.
6. Install the wheel and tire assembly and tighten the wheel nuts to the specified torque.
7. Perform an air spring fill procedure described in the next section.

Air Spring Inflation

If an air spring has been replaced, or the air has been completely exhausted from an air spring, a spring fill procedure is required to inflate the air spring. The air spring fill procedure varies depending on the vehicle make and model year. Always follow the air spring fill procedure in the vehicle manufacturer's service manual. The following air spring fill procedure is for a vehicle with the air springs separate from the shock absorbers.

The weight of the vehicle must not be allowed to compress an uninflated air spring.

When an air spring is being inflated, use this procedure:

1. With the vehicle chassis supported on a hoist, lower the hoist until a slight load is placed on the suspension. Do not lower the hoist until the suspension is heavily loaded.
2. Turn on the air suspension system switch.

CAUTION:
Do not allow the suspension to compress an air spring until the airspring is inflated. This action may damage the air spring.

3. Turn the ignition switch from Off to Run for 5 seconds with the driver's door open and the other doors shut. Turn the ignition switch off.
4. Ground the diagnostic lead.
5. Apply the brake pedal and turn the ignition to the Run position. The warning lamp will flash every 2 seconds to indicate the fill mode.
6. To fill a rear spring or springs, close and open the driver's door once. After a 6-second delay, the rear spring will fill for 60 seconds.
7. To fill a front spring or springs, close and open the driver's door twice. After a 6-second delay, the front spring will fill for 60 seconds.
8. When front and rear springs require filling, fill the rear springs first. Once the rear springs are filled, close and open the driver's door once to begin filling the front springs.
9. The spring fill mode is terminated if the diagnostic lead is disconnected from ground. Termination also occurs if the ignition switch is turned off or the brake pedal is applied.

Scan Tool Procedure for Air Spring Inflation

On some air suspension systems the **scan tool** is used to activate the air compressor and energize the appropriate air spring solenoid valve to inflate an air spring. The following is a typical spring fill procedure using a scan tool on an automatic air suspension system:

1. Turn off the air suspension switch.
2. Be sure the proper module is installed in the scan tool for suspension diagnosis and service on the vehicle being serviced.
3. Connect the scan tool to the **data link connector (DLC)** on the vehicle.
4. Be sure the vehicle is positioned on a frame-contact lift with the suspension dropped downward and no load on the suspension.
5. Connect a battery charger to the battery terminals with the correct polarity, and set the charger at a low charging rate.
6. Select Function Test on the scan tool, and select the desired function test number for the air spring being filled as follows: test number 212 – LH front air spring, test number 214 – RH front air spring, test number 216 – LH rear air spring, and test number 218 – RH rear air spring. When the proper function test number is selected, the scan tool commands the compressor and the appropriate air spring solenoid valve on, to allow air spring inflation.
7. When the compressor shuts off, the air spring inflation is complete, and any further air spring inflation or deflation is done during normal operation of the air suspension system.
8. Lower the vehicle onto the shop floor and completely lower the lift. Be sure the lift arms are not contacting the vehicle.
9. Inspect the air spring(s) that were completely deflated, and be sure there are no folds and creases in these springs.
10. Turn on the suspension switch.
11. If the lower front strut-to-control arm bolt and nut were removed and reinstalled during the suspension service procedure, use your knee to push downward and release the front bumper. Repeat this procedure three times.
12. Tighten the lower front strut-to-control arm nut and bolt to the specified torque.
13. Road test the vehicle and verify proper air suspension operation and trim height.

Photo sequence 13 shows the proper procedure for air spring inflation with a scan tool.

Trim Height Mechanical Adjustment

On some vehicles with air suspension, the trim height is adjusted by lengthening or shortening the front or rear height sensors. On other vehicles the manufacturer recommends using the scan tool to adjust the trim height. Always follow the trim height adjustment procedure in the vehicle manufacturer's service manual.

A **scan tool** is a digital tester that can be used to diagnose various on-board computer systems.

The **data link connector (DLC)** is a 16-terminal connector positioned under the left side of the instrument panel. A scan tool is connected to the DLC to diagnose various on-board electronic systems.

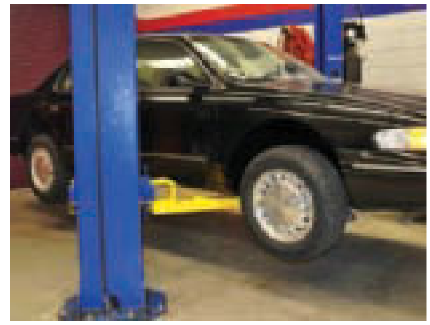
OBD II computer systems became mandatory on cars and light trucks in the 1996 model year. Some vehicles prior to 1996 were equipped with OBD II systems. OBD II systems have some standardized features such as a 16-terminal DLC under the left side of the dash. OBD II systems have increased monitoring capabilities in the PCM. Many engine control systems are monitored, and if any engine system is defective so it allows the exhaust emissions to increase more than 1.5 times the normal limit for that vehicle, the malfunction indicator light (MIL) illuminates in the instrument panel.

PHOTO SEQUENCE 13

Inflate L/H Front Air Spring Using a Scan Tool

P13-1 **Turn off the air suspension switch.**

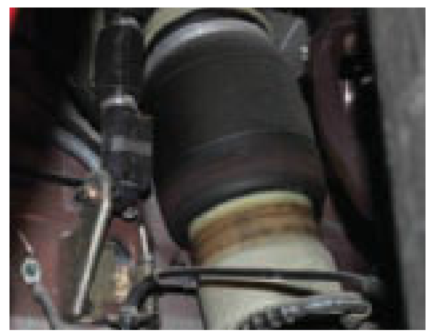
P13-2 **Connect the scan tool to the data link connector (DLC) on the vehicle.**



P13-3 **Be sure the vehicle is positioned on a frame-contact lift with the suspension dropped downward and no load on the suspension.**

P13-4 **Connect a battery charger to the battery terminals with the correct polarity, and set the charger at a low charging rate.**

P13-5 **Select Function Test on the scan tool, and select the desired Function Test number 212 – LH front air spring. When the proper function test number is selected, the scan tool commands the compressor and the appropriate air spring solenoid valve on, to allow air spring inflation.**



P13-6 **When the compressor shuts off, the air spring inflation is complete. Inspect the L/H front air spring and be sure there are no folds and creases in the spring.**

P13-7 **Shut the battery charger off and disconnect the charger cables. Lower the vehicle onto the shop floor and completely lower the lift. Be sure the lift arms are not contacting the vehicle.**

P13-8 **Disconnect the scan tool, and turn on the suspension switch.**

P13-9 **If the lower front strut-to-control arm bolt and nut were removed and reinstalled during the suspension service procedure, use your knee to push downward and release the front bumper. Repeat this procedure three times. Tighten the lower front strut-to-control arm nut and bolt to the specified torque.**

P13-10 **Road test the vehicle and verify proper air suspension operation and trim height.**

SERVICE TIP:
Some on-board diagnostic I (OBD I) vehicles have a separate suspension DLC positioned on the right-front strut tower. Other OBD I vehicles have the suspension DLC in the trunk. **OBD II computer systems** have a universal 16-terminal DLC mounted under the left side of the dash near the steering column (Figure 8-9). Data links are connected from various on-board computers including the suspension computer to the DLC to allow the on-board computers to communicate with the scan tool and vice versa.

The **trim height** should be measured on the front and rear suspension at the locations specified by the vehicle manufacturer (Figure 8-10).

If the rear suspension trim height is not within specifications, it may be adjusted by loosening the attaching bolt on the top height sensor bracket (Figure 8-11). When the bracket is moved one index mark up or down, the ride height is lowered or raised 0.25 in. (6.35 mm).

The front suspension trim height may be adjusted by loosening the lower height sensor attaching bolt. Three adjustment positions are located in the lower front height sensor bracket (Figure 8-12). If the height sensor attaching bolt is moved one position up or down, the front suspension height is lowered or raised 0.5 in. (12.7 mm).

Line Service

Nylon lines on the electronic air suspension system have quick disconnect fittings. These fittings should be released by pushing downward and holding the plastic release ring, and then pulling outward on the nylon line (Figure 8-13). Simply push the nylon line into the fitting until it seats to reconnect an air line.

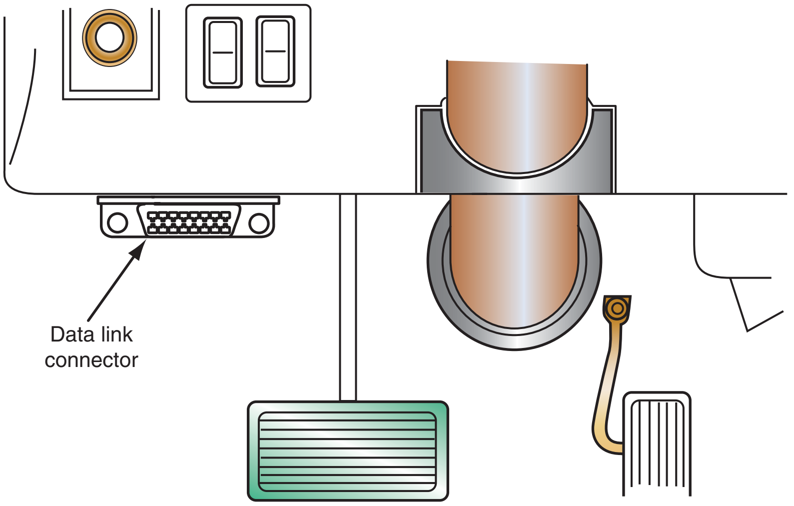


FIGURE 8-9 **Data link connector (DLC), on-board diagnostic II (OBD-II) system.**

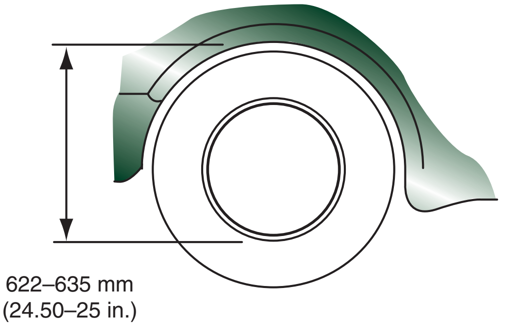


FIGURE 8-10 **Trim height measurement location.**

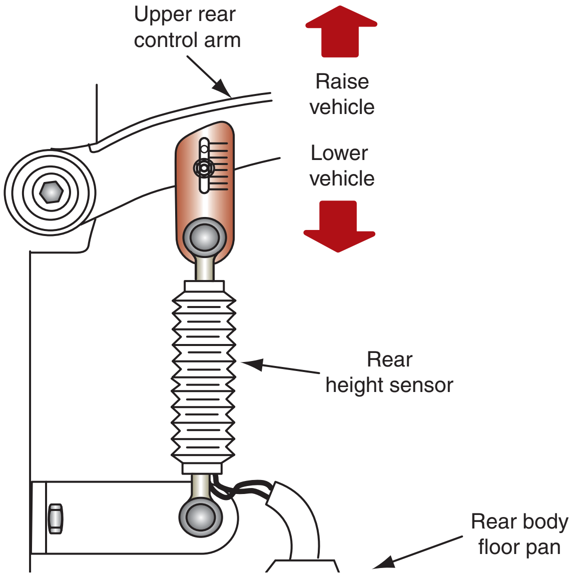


FIGURE 8-11 **Rear trim height adjustment.**

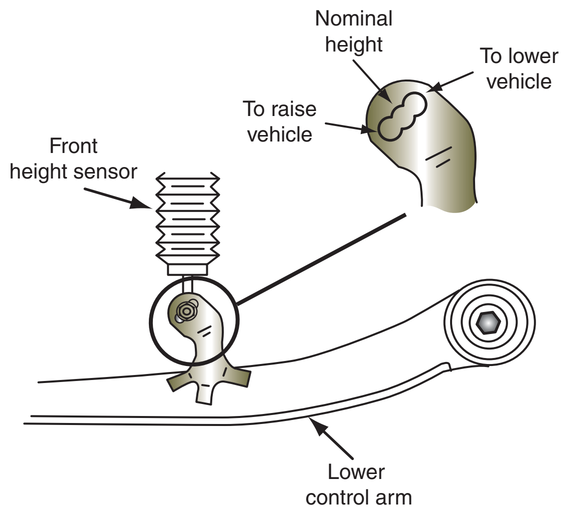


FIGURE 8-12 **Front trim height adjustment.**

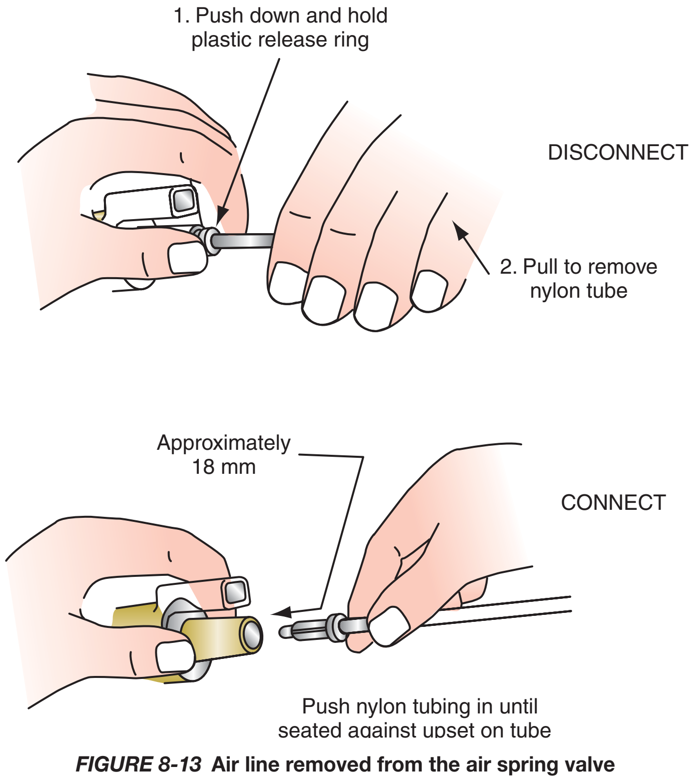


FIGURE 8-13 **Air line removed from the air spring valve or compressor outlets.**

Front and rear **trim height** is the distance between the vehicle chassis and the road surface measured at locations specified by the vehicle manufacturer.

If a line fitting is damaged, it may be removed by looping the line around your fingers and pulling on the line without pushing on the release ring (Figure 8-14). When a new collet and release ring are installed, the O-ring under the collet must be replaced. If a leak occurs in a nylon line, a sharp knife may be used to cut the defective area out of the line. A service fitting containing a collet fitting in each end is available for line repairs. After the defective area is cut out of the line, push the two ends of the line into the service fitting (Figure 8-14).

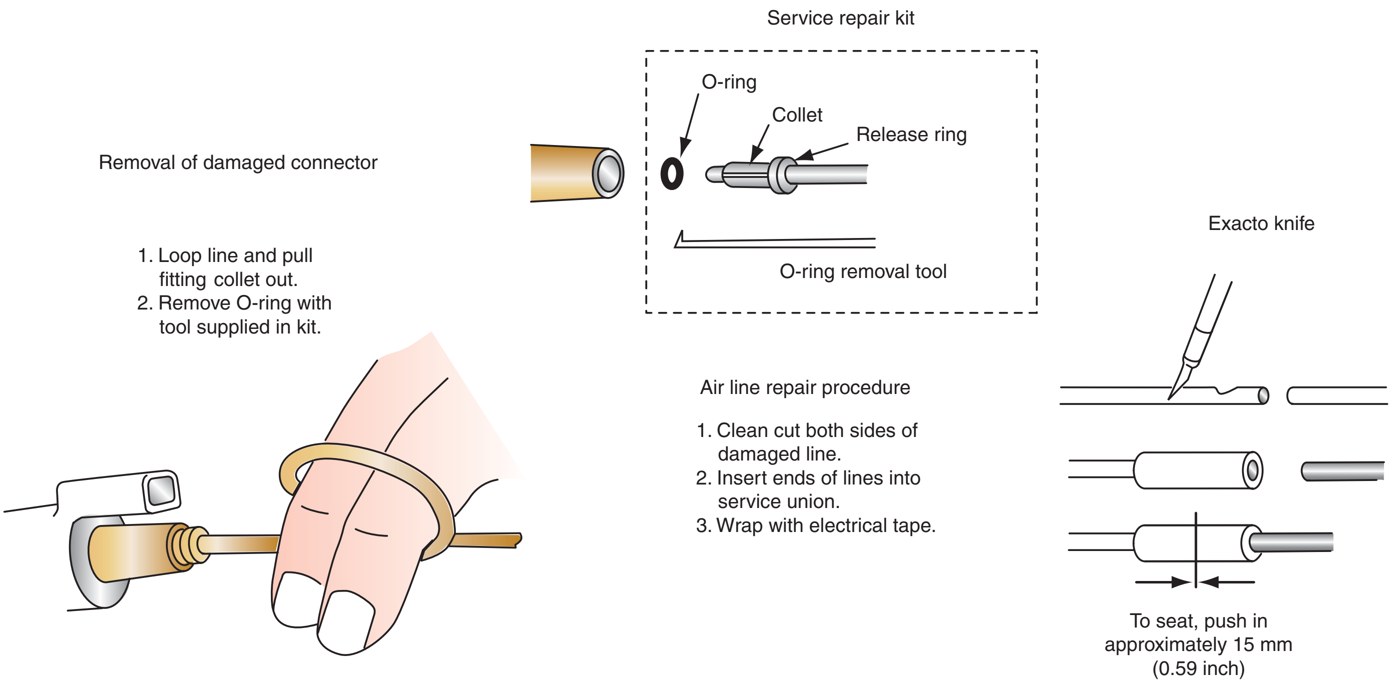


FIGURE 8-14 **Removing the quick disconnect fittings and air line repairs procedure.**

Servicing and Diagnosing Vehicle Dynamic Suspension Systems

On some vehicles the air suspension is referred to as a **vehicle dynamic suspension (VDS)**. Proper diagnosis of the VDS is extremely important to locate the exact root cause of the customer's complaint. Improper diagnosis may lead to wasted time and unnecessary replacement of expensive electronic components. The first step in VDS diagnosis is to visually inspect the system.

The **vehicle dynamic suspension** is an air suspension system used on some current model vehicles.

VDS Inspection and Verification

Follow these steps to inspect the VDS system and verify the symptoms:

1. Be sure the customer complaint is identified; road test the vehicle if necessary.
2. Be sure none of the DOOR AJAR indicators are illuminated.
3. Inspect the suspension system for anything that could result in restricted suspension movement.
4. Inspect the vehicle trunk for excessive loading.
5. Check the front and rear height sensors for loose or worn mountings.
6. Inspect the front and rear air springs for damage such as punctures and tears.
7. Check the suspension air lines for cuts, splits, or a crimped condition.
8. Check fuses 102, 30, 27, and 111 in the central junction box.
9. Inspect all VDS electrical connections for looseness and corrosion.
10. Be sure the air suspension switch is on.
11. Inspect the solenoid valves in the air springs for damage.

If the VDS inspection reveals an obvious problem, this defect must be corrected before proceeding with the electronic diagnosis. When the inspection and verification does not indicate any defects, proceed with the pneumatic test and the on-demand self-test.

SERVICE TIP: If a door ajar indicator is illuminated even when all the doors, liftgate, and liftgate glass are closed, the VDS will not operate properly. The problem with the door ajar indicator must be repaired before proceeding with the VDS diagnosis.

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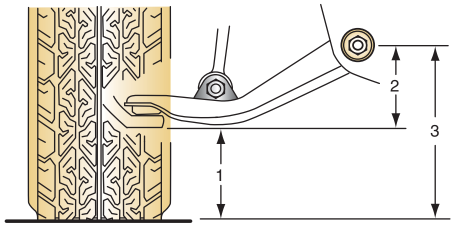
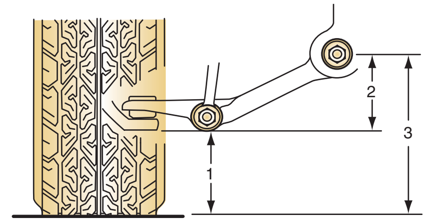
Ride Height Adjustment or Calibration

The ride height adjustment procedure with a scan tool may vary depending on the vehicle make and model year. The following is a typical ride height adjustment procedure with a



Item	Description
1	Distance between the ground and the lower knuckle surface near the ball joint
2	Ride height = 3 - 1
3	Distance between the ground and the center of the lower arm rearward mounting bolt

FIGURE 8-15 **Front ride height measurement.**



Item	Description
1	Distance between the ground and lower edge of arm below the shock absorber mounting bolt
2	Ride height = 3 - 1
3	Distance between the ground and the center of the lower arm mounting bolt

FIGURE 8-16 **Rear ride height measurement.**

scan tool for a 2005 Ford Expedition or Lincoln Navigator equipped with a vehicle dynamic suspension:

1. Be sure the air suspension switch is in the On position.
2. Be sure the battery is fully charged.
3. Turn off the ignition switch and exit the vehicle. Close all doors and wait 45 seconds for the air suspension system to vent down to the Kneel position.
4. Open the driver's door, and turn on the ignition switch.
5. Shift the transmission into drive and back into park.
6. Exit the vehicle, close all the doors, and wait 45 seconds for the suspension system to pump up to the trim height.
7. Use a tape measure to measure the ride height at the locations specified by the vehicle manufacturer (Figures 8-15 and 8-16).
8. If the ride height does not equal the manufacturer's specifications, open the left-front door, and connect the scan tool to the DLC. Be sure the scan tool contains the proper module for the vehicle being tested.
9. Select the correct vehicle year, model, and engine type on the scan tool, and then select *Vehicle Dynamic Module* (VDM).
10. Use the active command mode in the scan tool to vent or lift the vehicle to achieve the specified trim height.
11. When a tape measure indicates the specified front and rear ride height, select *Save Calibration Values* on the scan tool to calibrate the VDM to the specified trim height.
12. Road test the vehicle and verify the proper suspension height.

SERVICE TIP: The ride height adjustment procedure must be completed before a wheel alignment is performed.

SERVICE TIP: The ride height adjustment must be performed after a VDM is replaced.

Pneumatic Test

The pneumatic test verifies the air lines are connected and the air compressor, air compressor vent solenoid, and air spring solenoid valves are functioning properly. Follow these steps to complete the pneumatic test:

1. Close all doors, liftgate, and liftgate glass.
2. Place the transmission selector in park.
3. Be sure the air suspension switch is on.
4. Connect the scan tool to the DLC. Be sure the correct module is installed in the scan tool.
5. Turn on the ignition switch and select *Vehicle Dynamic Module* followed by *Pneumatic Test* on the scan tool.

6. This scan tool selection causes the VDM to operate the VDS compressor, spring solenoid valves, and vent valve. While operating the system the VDM checks for proper response from the height sensors. If the VDM does not perform normal air spring fill and vent operations in the required time, the VDM sets diagnostic trouble codes (DTCs) in memory and displays appropriate messages in the message center or in the instrument panel if the vehicle does not have a message center. The results of the pneumatic test are also displayed on the scan tool.

On-Demand Self-Test

When the inspection, verification, and pneumatic tests do not indicate any defects, the on-demand self-test should be performed to locate the problem area in the VDS system.

Complete the following steps to perform the on-demand self-test:

1. Be sure the transmission is in park.
2. Be sure the battery is fully charged. A battery charger may be installed to maintain a fully charged battery.
3. Connect the scan tool to the DLC.
4. Lower the driver's window and close all doors, liftgate, and liftgate glass.
5. Be sure the 4L mode is not selected on four-wheel-drive models.
6. Turn on the ignition switch.
7. Select *Vehicle Dynamic Module* and *On-Demand Self-Test* on the scan tool.
8. Record all DTCs displayed on the scan tool.
9. Turn off the ignition switch.

When DTCs are displayed on the scan tool, interpret the meaning of the DTC and diagnose the root cause of the problem. Possible DTCs on the VDS system are these:

1. B1317 – high battery voltage
2. B1318 – low battery voltage
3. B1342 – VDM is defective
4. B2477 – variable assist power steering (VAPS) steering assist curve not complete
5. C1445 – vehicle speed sensor circuit defect
6. C1724 – air suspension height sensor power circuit failure
7. C1725 – air suspension front pneumatic failure
8. C1726 – air suspension rear pneumatic failure
9. C1760 – failure in rear height sensor signal circuit
10. C1770 – failure in vent solenoid output circuit
11. C1790 – L/R air spring solenoid valve output circuit failure
12. C1795 – R/R air spring solenoid valve output circuit failure
13. C1830 – failure in compressor relay circuit
14. C1840 – failure in air suspension On/Off switch
15. C1873 – R/F air spring solenoid valve output circuit failure
16. C1877 – L/F air spring solenoid valve output circuit failure
17. C1881 – failure in R/F height sensor circuit
18. C1889 – failure in L/F height sensor circuit
19. C1897 – failure in VAPS circuit loop
20. C1964 – compressor run time longer than specified
21. C1990 – VDM initialization required on replacement VDM
22. C1991 – factory trim height setting and/or tests not completed
23. U1900 – missing controller area network (CAN) messages
24. U2023 – improper CAN messages

If DTCs are displayed on the scan tool, detailed pinpoint tests are provided in the vehicle manufacturer's service manual to locate the exact cause of the problem. These pinpoint tests

usually include voltmeter and ohmmeter tests. A DTC indicates the area in which a problem is present, but the pinpoint tests are used to locate the root cause of the defect. When DTC C1990 is displayed, perform the pneumatic test and ride height calibration procedure to initialize the VDM.

CAUTION: When removing and replacing components on the VDS, the vehicle manufacturer recommends replacing all the self-locking nuts. Failure to observe this service procedure may cause loose suspension components and component failure.

Removal and Disassembly of Combined Air Springs and Shock Absorbers on VDS Systems

The removal and disassembly procedures are similar for front and rear air springs. Follow these steps to remove and disassemble a combined air spring and shock absorber:

1. Position the vehicle on a lift and place the lift arms under the specified lift points on the vehicle.
2. Be sure the ignition switch and the VDS switch are turned off.
3. Connect the scan tool to the DLC, and use the scan tool to vent the air spring being removed.

WARNING: Never remove an air spring or a component attached to the air spring without completely deflating the air spring. This action may cause personal injury.

4. Remove the upper strut mount retaining nuts on the air spring to be removed (Figure 8-17). Discard the nuts.
5. Raise the vehicle to a comfortable working height. Disconnect the electrical connector from the air spring solenoid valve (Figure 8-18).
6. Compress the orange quick-disconnect connector on the air line connected to the air spring, and pull downward to disconnect the air line (Figure 8-19).
7. Use the appropriate socket and ratchet to remove the nut from the lower shock absorber mounting bolt, and remove this bolt (Figure 8-20).
8. Remove the air spring and shock absorber from the chassis.
9. Place a wrench on the hex on top of the shock absorber rod, and hold this rod from turning while loosening and removing the nut on the top of the shock absorber rod (Figure 8-21).
10. Place index marks on the lower end of the air spring and shock absorber so these components may be reassembled in the original position. Depress the retainer tabs on the bottom end of the air spring, and remove the air spring from the shock absorber (Figure 8-22).
11. Remove and discard the seal and washer on the upper end of the shock absorber rod (Figure 8-23).

SERVICE TIP: If the retainer tabs on the lower end of the air spring are broken, air spring replacement is necessary.

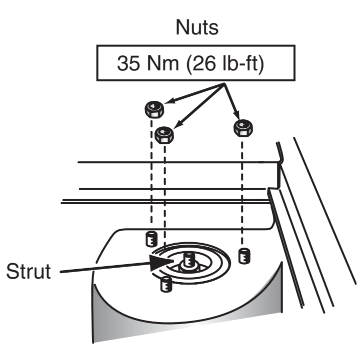


FIGURE 8-17 **Removing the upper mount retaining nuts.**

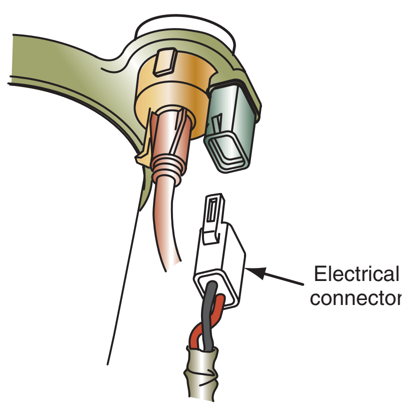


FIGURE 8-18 **Disconnecting the electrical connector from the air spring solenoid valve.**

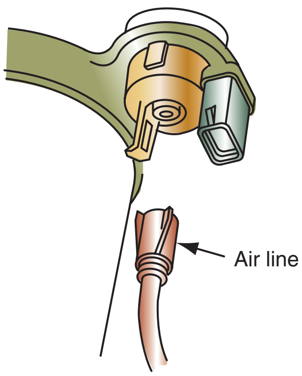


FIGURE 8-19 **Disconnecting the air line from the air spring solenoid valve.**

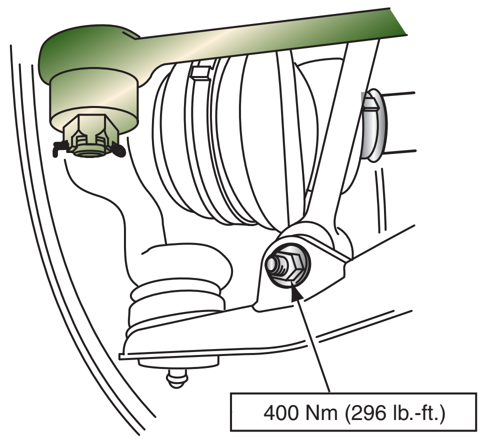


FIGURE 8-20 **Removing the lower shock absorber retaining bolt and nut.**

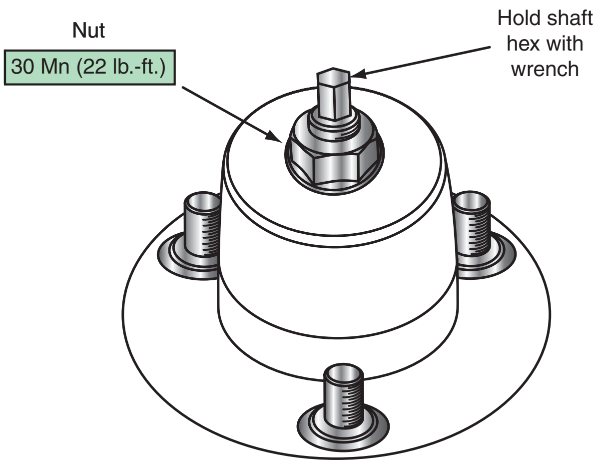


FIGURE 8-21 **Removing the nut from the upper end of the shock absorber rod.**

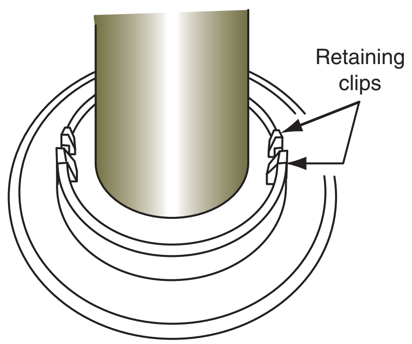


FIGURE 8-22 **Depressing the retaining tabs on the bottom end of the air spring.**

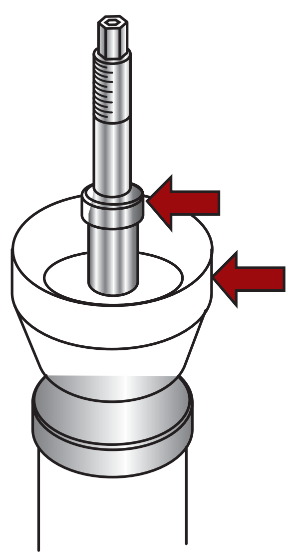


FIGURE 8-23 **Seal and washer on the upper end of the shock absorber rod.**

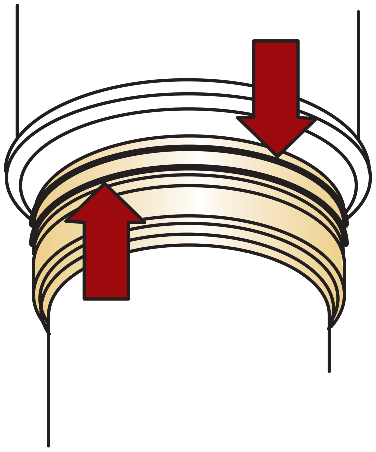


FIGURE 8-24 **O-ring seals on the lower sealing area on the shock absorber.**

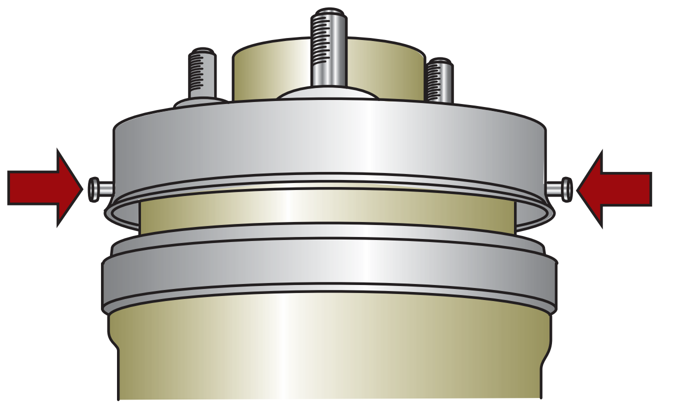


FIGURE 8-25 **Retaining pins on the upper air spring mount.**

CAUTION:
Never remove or install the wiring connector on a computer or computer system component with the ignition switch on. This action may result in computer damage.

CAUTION:
Do not supply voltage to or ground any circuit or component in a computer system unless instructed to do so in the vehicle manufacturer's service manual. This action may damage computer system components.

CAUTION:
During computer system diagnosis, use only the test equipment recommended in the vehicle manufacturer's service manual to prevent damage to computer system components.

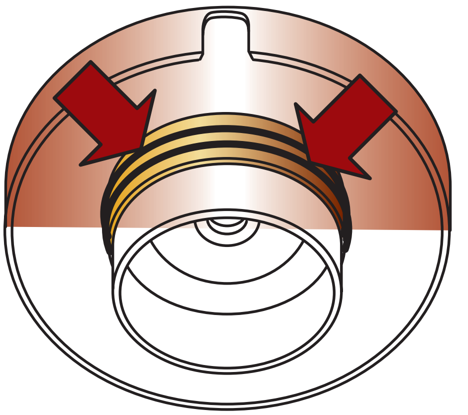


FIGURE 8-26 **O-ring seals on the upper spring mount.**

12. Remove and discard the O-ring seals on the lower sealing area between the shock absorber and the air spring (Figure 8-24).
13. Remove and discard the retainer pins that hold the upper mount onto the air spring (Figure 8-25).
14. Remove and discard the O-ring seals on the upper mount area that provides a seal between the mount and the air spring (Figure 8-26).

When reassembling the air spring and shock absorber, replace all the O-rings and self-locking nuts, and place a light coating of chassis lubricant on all the O-rings.

Diagnosis of Electronic Suspension Control Systems

Diagnostic Trouble Code (DTC) Display

Vehicles equipped with the **electronic suspension control (ESC)** system may have a digital or an analog instrument panel cluster (IPC). If the vehicle has a digital IPC, the air-conditioning (A/C) control panel is contained in the IPC (Figure 8-27). A driver message center is located in the center of the IPC underneath the speedometer. This message center is a vacuum fluorescent (VF) display with twenty characters. The same message center is mounted in an analog IPC (Figure 8-28). If the car has an analog IPC, the A/C controls are mounted in a separate display (Figure 8-29).

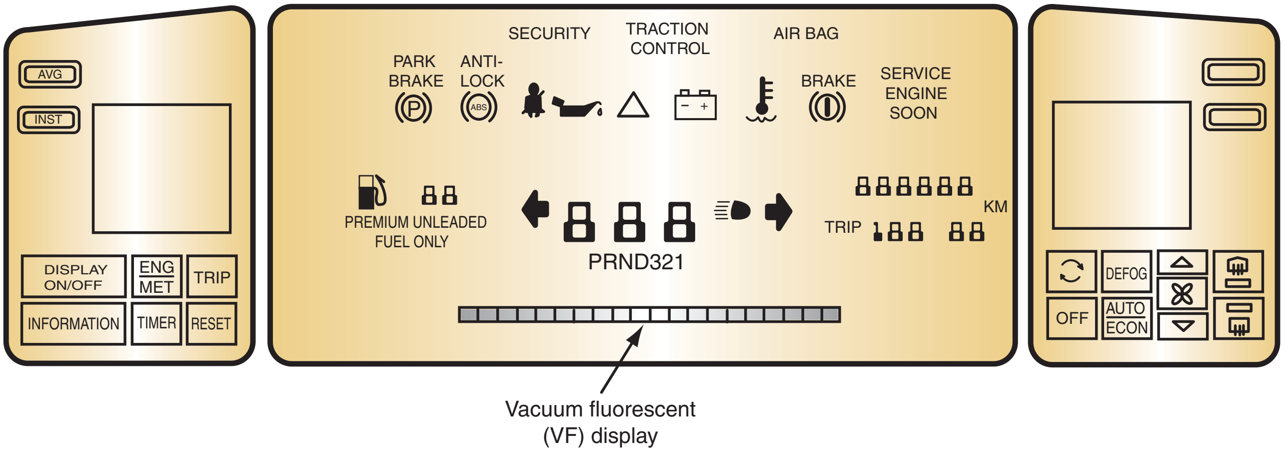


FIGURE 8-27 **Digital instrument panel cluster.**

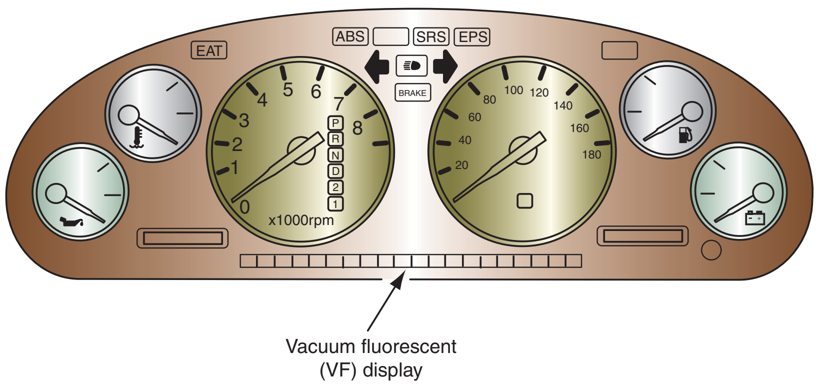


FIGURE 8-28 **Analog instrument panel cluster.**

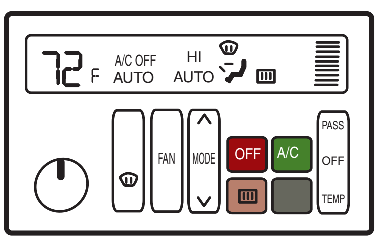


FIGURE 8-29 **A/C controls used with the analog instrument panel cluster.**

Early versions of the ESC system may be called **continuously variable road sensing suspension (CVRSS)** systems.

When the information (INFO) button is pressed in the IPC, the driver message center cycles through a series of status messages: RANGE, AVG MPG, MPG INST, FUEL USED, OIL LIFE LEFT, ENGINE RPM, BATTERY VOLTS, COOLANT TEMP, ENGLISH/METRIC RESET. The parameters related to fuel usage are not displayed in the message center on a digital IPC, because these readings are displayed in the fuel data center that is contained in the IPC.

If an electrical defect occurs in the ESC system, a SERVICE RIDE CONTROL message is displayed in the driver information center, and a diagnostic trouble code (DTC) is usually stored in the ESC module. The first step in diagnosing the ESC system should be a thorough visual inspection of the system. Inspect the wiring harness for damaged wires and loose or corroded connectors. Be sure the battery is fully charged and all the fuses are in good condition.

SERVICE TIP:

When removing, replacing, or servicing an electronic component on a vehicle, always disconnect the negative battery cable before starting the service procedure. If the vehicle is equipped with an air bag or bags, wait one minute after the battery negative cable is removed to prevent accidental air bag deployment. Many air bag computers have a backup power supply capable of deploying the air bag for a specific length of time after the battery is disconnected.

If the SERVICE RIDE CONTROL message is displayed, the technician enters the diagnostic mode by pressing the OFF and WARMER buttons simultaneously on the A/C controls with the ignition switch on. When these buttons are pressed, the IPC performs a segment check in which all segments in the IPC and climate control panel (CCP) are illuminated for a brief period of time. Press the low fan speed button to display the abbreviation for the on-board computers, such as PCM and IPC, one after the other. Continue pressing the low fan speed button until ESC appears in the driver message center. When ESC is displayed, press the increase fan speed button to select this parameter. When this action is taken, the ESC DTCs are displayed in the driver message center. Each DTC is designated as CURRENT or HISTORY, and each DTC has a C prefix followed by four digits. If there are no DTCs in the ESC module, NO ESC CODES is displayed. When NO ESC DATA is displayed, there is an electrical defect in the data link, the module ground connection, or in the ESC module battery or ignition inputs. A DTC represents a fault in a certain area of the ESC system. For example, if a C1711 is displayed, there is a short to ground in the left front (LF) damper actuator. The technician has to perform voltmeter or ohmmeter test procedures provided in the appropriate service manual to test the LF damper actuator and the related sensor wiring to locate the exact cause of the defect. When the ohmmeter leads are connected to the damper actuator terminals on the strut, the ohmmeter should indicate 9.5 to 15.5 ohms. The DTCs and ESC system specifications may vary depending on the vehicle make, model, and year. If the ohmmeter reading is infinite, the damper actuator has an open circuit. An ohmmeter reading below this value indicates a shorted damper actuator. If the ohmmeter leads are connected from one of the damper actuator terminals to ground, the ohmmeter should provide an infinite reading indicating this actuator is not grounded. When the ohmmeter indicates a low reading, the damper actuator is shorted to ground. Ohmmeter tests for shorts-to-ground and open circuits must also be performed on the wires from the damper actuator to the ESC module. The DTCs are displayed in the driver message center. The DTCs may be cleared from the ESC module by pressing the increase fan speed button when CLEAR DTCS is displayed in the driver message center. A scan tool may also be used to clear the DTCs. Disconnecting the battery or the ESC module connector will not clear the DTCs.

A scan tool also displays the DTCs and diagnoses the ESC system. The scan tool displays the voltage data from the wheel position sensors, steering sensor, vehicle speed sensor, and battery.

Scan Tool Diagnosis of Electronic Suspension Control

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When diagnosing an ESC system, the first step is to identify the complaint. Listen to the customer's complaint, and road test the car if necessary to determine the exact problem. The next step in the diagnostic procedure is to visually inspect all ESC components. Check all the ESC wiring connections and wiring harnesses. Be sure all the ESC fuses are satisfactory. Check the shock absorbers, struts, and other suspension components for loose mountings and damage. Inspect the shock absorbers and struts for fluid leaks. Be sure the battery is fully charged.

Observe the message center for displayed messages related to the ESC system. ESC systems with computer-controlled solenoids in the shock absorbers or struts display SERVICE SUSPENSION SYSTEM or SPEED LIMITED TO XXX if a defect occurs in the ESC. If the vehicle has an ESC system with magneto-rheological fluid in the shock absorbers or struts, the ESC system displays SHOCKS INOPERATIVE, SERVICE RIDE CONTROL, OR MAXIMUM SPEED 129 km/h (80 mph) if a defect occurs in the system. The messages indicating a limited maximum vehicle speed are displayed only when the ESC module has detected a defect and shut down the electronic control of all shock absorbers or struts.

To locate a defect in an ESC system the next step is to perform a diagnostic system check. This check identifies the control modules in the system, and tests the ability of the control

modules to communicate through the data link system. The diagnostic system check also displays all DTCs in the various modules related to ESC.

Follow these steps to complete a diagnostic system check:

1. Be sure the ignition switch is off, and connect a scan tool to the DLC.
2. Turn on the ignition switch.
3. Use the scan tool to select the various modules related to ESC control. These modules include the **powertrain control module (PCM)**, ESC module, and the electronic brake control module (EBCM).
4. Use the scan tool to display all the DTCs stored in each of the modules in step 3. Record all DTCs.
5. If a DTC is displayed that begins with a U, there is a problem with communications through the data links. When one or more of the displayed DTCs begins with a U, a lack of communication between the scan tool and one or more of the modules likely occurred in step 3.
6. The cause of the DTC beginning with a U must be corrected before proceeding with any further diagnosis. After the cause of the data link DTC is corrected, diagnose the cause of all other DTCs.

The **powertrain control module (PCM)** controls engine functions.

The following DTCs represent ESC defects:

1. C0550 – ESC module malfunction.
2. C0563 – ESC module calibration defect.
3. C0577, C0579, C0582, C0584, C0587, C0589, C0592, C0594 – the voltage is out of the normal range in one of the strut solenoids or electromagnets. Detailed DTC explanations and diagnostic procedures are provided in the vehicle manufacturer's service manual.
4. C0578, C0583, C0588, C0593 – ESC fault in one of the internal ESC module drivers that operate the strut solenoids or electromagnets.
5. C0615, C0620, C0625, C0630 – a fault exists in one of the position sensors that causes the sensor voltage to be below or above the normal range of 0.35 V to 4.75 V for more than 1 second.
6. C0635, C0638, C0640, C0643, C01252, C01253 – a defect in the two normal force signal circuits between the ESC module and the electronic brake control module (EBCM). The ESC module controls each shock absorber or strut actuator with a pulse width modulated (PWM) duty cycle or 10% to 90% depending on road surface conditions. The ESC module relays this PWM information through a normal force signal circuit to the EBCM, and the EBCM uses this information to provide improved braking on irregular road surfaces.
7. C0665 – the ESC module did not detect a low-to-high change in the lift/dive circuit within 31 seconds after it received the ignition switch on signal.
8. C0690, C0691, C0693 – a defect in the damper control relay circuit that is integral in the ESC module. If one or more of these DTCs is displayed, ESC module replacement is necessary.
9. C0696 – the 5 V reference voltage sent from the ESC module to each position sensor is out of the normal range of 3.75 V to 5.6 V.
10. C0710 – the ESC module does not detect a valid steering position signal from the EBCM for 5 seconds. The EBCM controls the ABS and the variable assist steering.
11. C0896 – the battery voltage is not within the normal range of 9 V to 15.5 V.
12. P1652 – the output driver module (ODM) in the PCM that controls suspension lift/dive has detected an improper circuit condition.

To set most DTCs in the ESC module, the module must sense a defect on three consecutive ignition cycles, or during the same ignition cycle after clearing the DTC with a scan tool.

Scan Tool Data Display

Select *Special Functions* on the scan tool to access the ESC system data. The ESC data is very helpful to pinpoint the exact cause of DTCs. The following ESC data may be displayed on the scan tool with the ignition switch on, the engine off, and the front wheels straight ahead:

1. Battery voltage signal – typical data 12.6 V.
2. DSP software version ID – numerical value.
3. EEPROM calibration ID – numerical value.
4. GM part number ESC module – numerical value.
5. ESC module software version – numerical value.
6. L/F damper actuator command – 0% to 100% – this percentage indicates the commanded on-time of the damper actuator. If the ESC module commands the damper actuator On, the percentage increases.
7. L/F position sensor – 0 V to 5 V – this voltage is the signal voltage sent from the position sensor to the ESC module. If downward force is supplied to the L/F of the chassis, the voltage reading should change. When the position sensor voltage does not change, the sensor and connecting wires must be tested to locate the exact cause of the problem. After repairs have been completed to correct a problem causing a DTC, the scan tool must be used to clear the DTC from the ESC module.
8. L/F normal force – 20% to 80% – this percentage indicates a measured level of the road surface condition sent from the ESC module to the EBCM, and the EBCM uses this information to improve antilock braking on irregular road surfaces.
9. The damper actuator command and position sensor data are displayed on the scan tool for the other three corners of the chassis. The normal force data is available only on the front wheels.
10. Lift/Dive status – active, inactive – if there is no change in chassis pitch, the scan tool displays Inactive. When a change is chassis pitch occurs, the scan tool displays Active.
11. Lift/Dive change – changed, unchanged – if there is no change in chassis pitch, Unchanged is displayed on the scan tool. A change in chassis pitch causes the scan tool to display Changed.
12. Steering position PWM – 0 to 10 ms– this PWM signal is sent from the EBCM to the ESC module when the steering wheel is turned while cornering. The ESC module commands a firmer shock absorber state when the vehicle is turning a corner.
13. Vehicle speed – 0 to 159 mph (0 to 255 km/h) – the vehicle speed sensor signal is relayed on the data links from the PCM to the ESC module.

Scan Tool Output Controls

The Output Controls are accessed on the scan tool under the Special Functions menu. When Output Controls are selected on the scan tool, followed by an individual damper solenoid selection, the solenoid is cycled on and off. When an individual damper solenoid actuator is cycled on and off, the technician may perform voltage tests to check the damper actuator and related circuit. The scan tool may also be used to cycle all the damper solenoids simultaneously.

In the Output Controls mode, the scan tool may be used to command the ESC module to send the L/F and R/F normal force percentage readings to be sent to the EBCM, and this percentage is displayed on the scan tool.

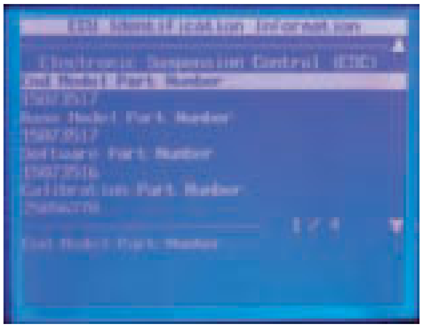
ESC Module Recalibration may also be selected on the scan tool in the Output Controls mode. This recalibration is necessary after a module replacement.

Photo Sequence 14 illustrates the procedure for reading scan tool data on an electronic suspension control system.

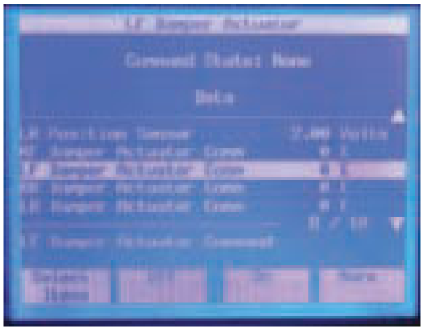
Reading Scan Tool Data on an Electronic Suspension Control System

P14-1 **Connect the scan tool to the DLC under the dash.**

P14-2 **Turn on the ignition switch, and select Special Functions in the ESC menu on the scan tool.**



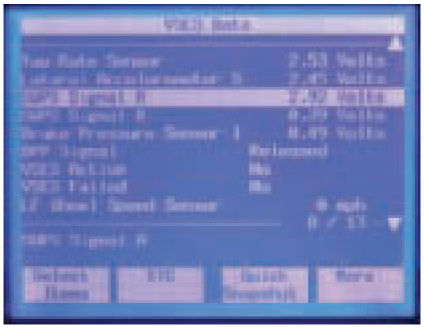
P14-3 **Display and record the DSP software version ID, EEPROM Calibration ID, GM part number ESC module, and ESC module software version on the scan tool.**



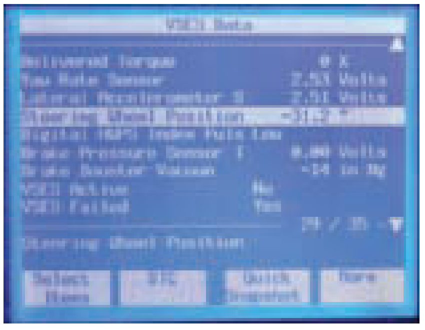
P14-4 **Select the damper actuator command on each damper actuator. This percentage indicates the commanded on-time of the damper actuator.**

P14-5 **Select the wheel position sensor voltage on each wheel position sensor. This voltage is the signal voltage sent from the position sensor to the ESC module.**

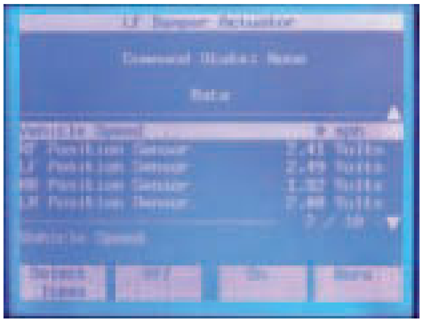
P14-6 **Select the normal force display on the scan tool. This percentage indicates a measured level of the road surface condition sent from the ESC module to the EBCM, and the EBCM uses this information to improve antilock braking on irregular road surfaces.**



P14-7 **Select the Lift/Dive status on the scan tool.**



P14-8 **Select Steering Position PWM on the scan tool.**



P14-9 **Select Vehicle Speed on the scan tool.**

The **antilock brake system (ABS)** prevents wheel lockup during a brake application.

The **Stabilitrak®** system is a type of vehicle stability control.

The **electronic brake and traction control module (EBTCM)** controls ABS, TCS, and Stabilitrak® functions.

The **brake pressure modulator valve (BPMV)** controls brake fluid pressure to the wheel calipers or cylinders.

Diagnosis of Stability Control System

The stability control system module is combined with the **antilock brake system (ABS)** and traction control system (TCS) modules. Therefore, it is not possible to completely separate the diagnosis of these systems. However, our discussion is mostly concerned with the stability control system, and this diagnostic information pertains to the **Stabilitrak®** system. The Stabilitrak® system may be called a vehicle stability enhancement system (VSES).

The **electronic brake and traction control module (EBTCM)** performs an initialization test each time the vehicle is started and the EBTCM does not receive a brake switch input. During the initialization test, the EBTCM cycles each solenoid valve and the pump motor in the **brake pressure modulator valve (BPMV)** for 1.5 seconds. If the EBTCM detects an electrical fault during the initialization test, a DTC is set in the EBTCM, and the amber ABS light and the red brake light may be illuminated in the instrument panel, depending on the severity of the defect. During the initialization test, the customer may hear the solenoids clicking and the pump motor turning in the BPMV.

The first step in diagnosing the stability control system is a visual inspection of all system components, such as the module connectors, fuses, relays, wiring harness, and sensor mounting and wiring connector.

If the visual inspection did not reveal any problems, the next step is to perform a Stabilitrak® diagnostic test drive as follows:

1. Turn the ignition switch off.
2. Connect a scan tool to the data link connector (DLC) under the instrument panel. Be sure the correct module for the system being tested is securely installed in the bottom of the scan tool.
3. Start the engine.
4. Monitor the "steering wheel centered" parameter on the scan tool, and be sure the scan tool displays "Yes" while driving the vehicle straight ahead above 15 mph (24 km/h).
5. Drive the vehicle for at least 10 minutes under a variety of driving conditions: highway driving, rough road driving, and turning maneuvers, including freeway ramps and sharp turns on parking lots.
6. Perform any driving maneuvers under which the customer complaint(s) occurred.
7. With the engine still running, observe and record any DTCs displayed on the scan tool.

If there is a defect in the Stabilitrak® system, "Stability Reduced" may be displayed in the driver information center. When "Display ABS/TCM/ICCS DTCs" is selected on the scan tool, any of the following DTCs may be displayed as indicated in Figures 8-30 and 8-31. The technician usually has to perform voltmeter or ohmmeter tests to locate the exact cause of a problem in the area indicated by the DTC.

Automated Test

An automated test may be selected on the scan tool. During this test, the EBTCM cycles all the solenoid valves and the pump motor in the BPMV, and DTCs are set in the EBTCM if there are defects in these components. This test is the same as the initialization test performed by the EBTCM when the engine is started. The scan tool also performs solenoid tests.

Valve Solenoid/Pressure Hold Test

To perform the valve solenoid/pressure hold test, follow this procedure:

1. Be sure the scan tool is properly connected to the DLC.
2. Turn on the ignition switch.

DTC	DESCRIPTION
C1211	ABS Indicator Lamp Circuit Malfunction
C1214	Solenoid Valve Relay Contact or Coil Circuit Open
C1217	BPMV Pump Motor Relay Contact Circuit Open
C1221	LF Wheel Speed Sensor Input Signal - 0
C1222	RF Wheel Speed Sensor Input Signal - 0
C1223	LR Wheel Speed Sensor Input Signal - 0
C1224	RR Wheel Speed Sensor Input Signal - 0
C1225	LF - Excessive Wheel Speed Variation
C1226	RF - Excessive Wheel Speed Variation
C1227	LR - Excessive Wheel Speed Variation
C1228	RR - Excessive Wheel Speed Variation
C1232	LF Wheel Speed Sensor Circuit Open or Shorted
C1233	RF Wheel Speed Sensor Circuit Open or Shorted
C1234	LR Wheel Speed Sensor Circuit Open or Shorted
C1235	RR Wheel Speed Sensor Circuit Open or Shorted
C1236	Low System Voltage
C1237	High System Voltage
C1238	Brake Thermal Model Limit Exceeded
C1241	Magna Steer® Circuit Malfunction
C1242	BPMV Pump Motor Ground Circuit Open
C1243	BPMV Pump Motor Stalled
C1251	RSS Steering Sensor Data Malfunction
C1252	ICCS2 Data Link Left Malfunction
C1253	ICCS2 Data Link Right Malfunction
C1255 xx	EBTCM Internal Malfunction (ABS/TCS/ICCS Disabled)
C1256 xx	EBTCM Internal Malfunction
C1261	LF Hold Valve Solenoid Malfunction

FIGURE 8-30 **DTCs for ABS/TCS/ICCS systems.**

3. Raise the vehicle on a lift so all four wheels are at least 6 in. (15 cm) off the floor.
4. Select Valve Solenoid Test on the scan tool followed by Hold Pressure on a specific wheel.
5. Hold the brake pedal in the applied position.
6. Have a co-worker try to turn the wheel being tested. If the hold pressure solenoid is operating properly, the co-worker should be able to turn the wheel.
7. Repeat steps 4 through 6 on the other wheels.

CUSTOMER CARE: While discussing computer-controlled suspension systems with customers, remember that the average customer is not familiar with automotive electronics terminology. Always use basic terms that customers can understand when explaining electronic suspension problems. Most customers appreciate a few minutes spent by service personnel to explain their automotive electronic problems. It is not necessary to provide customers with a lesson in electronics, but it is important that customers understand the basic cause of the problem with their vehicle so they feel satisfied the repair expenditures are necessary. A satisfied customer is usually a repeat customer.

DTC	DESCRIPTION
C1262	LF Release Valve Solenoid Malfunction
C1263	RF Hold Valve Solenoid Malfunction
C1264	RF Release Valve Solenoid Malfunction
C1265	LR Hold Valve Solenoid Malfunction
C1266	LR Release Valve Solenoid Malfunction
C1267	RR Hold Valve Solenoid Malfunction
C1268	RR Release Valve Solenoid Malfunction
C1271	LF TCS Master Cylinder Isolation Valve Malfunction
C1272	LF TCS Prime Valve Malfunction
C1273	RF TCS Master Cylinder Isolation Valve Malfunction
C1274	RF TCS Prime Valve Malfunction
C1276	Delivered Torque Signal Circuit Malfunction
C1277	Requested Torque Signal Circuit Malfunction
C1278	TCS Temporarily Inhibited By PCM
C1281	Stabilitrak® Sensors Uncorrelated
C1282	Yaw Rate Sensor Bias Circuit Malfunction
C1283	Excessive Time to Center Steering
C1284	Lateral Accelerometer Sensor Self-Test Malfunction
C1285	Lateral Accelerometer Sensor Circuit Malfunction
C1286	Steering/Lateral Accelerometer Sensor Bias Malfunction
C1287	Steering Sensor Rate Malfunction
C1288	Steering Sensor Circuit Malfunction
C1291	Open Brake Lamp Switch During Deceleration
C1293	DTC C1291 Set In Current or Previous Ignition Cycle
C1294	Brake Lamp Switch Circuit Always Active
C1295	Brake Lamp Switch Circuit Open
C1297	PCM Indicated Brake Extended Travel Switch Failure
C1298	PCM Indicated Class 2 Serial Data Link Malfunction
U1016	Loss of PCM Communications
U1056	Loss of CVRSS Communications
U1255	Generic Loss of Communications
U1300	Class 2 Circuit Shorted to Ground
U1301	Class 2 Circuit Shorted to Battery +

FIGURE 8-31 **DTCs for ABS/TCS/ICCS systems. (continued)**

Valve Solenoid/Pressure Release Test

To perform a valve solenoid/pressure release test, follow this procedure:

1. Be sure the scan tool is properly connected to the DLC.
2. Turn on the ignition switch.
3. Raise the vehicle on a lift so all four wheels are at least 6 in. (15 cm) off the floor.
4. Hold the brake pedal in the applied position.
5. Select Valve Solenoid Test on the scan tool followed by Release Pressure on a specific wheel.
6. Have a co-worker try to turn the wheel being tested. If the release pressure solenoid is operating properly, the co-worker should be able to turn the wheel.
7. Repeat steps 4 through 6 on the other wheels.

If any of the hold or release solenoids do not operate properly, the BPMV requires replacement. The solenoids in the BPMV are not serviceable.

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Diagnosis of Vehicle Networks

Vehicle networks have various voltages and operating characteristics. Therefore, the vehicle manufacturer's specific diagnostic procedure must be followed for each vehicle network. The most common equipment for diagnosing vehicle networks are a scan tool, a digital volt ohm meter (DVOM), and a lab scope. If a defect occurs in most networks, a DTC(s) is displayed on a scan tool connected to the DLC. The technician must follow the vehicle manufacturer's specified procedure to diagnose the cause of the DTC(s). When using a lab scope to diagnose vehicle networks, the technician must be familiar with the normal lab scope pattern for each network. We will discuss the lab scope patterns for two common networks and provide several case studies of network diagnosis.

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A Class 2 network is a single-wire system. When the system is at rest with no communication taking place, the system voltage is 0 V. When communication takes place on this network, the data are transmitted by a variable pulse width signal of 0–7 V. The Class 2 network is connected to terminal 2 in the DLC, and it also interconnects with various computers depending on the electronic equipment on the vehicle. To diagnose a Class 2 network with a lab scope, connect the Channel 1 positive lead of the scope to pin 2 in the DLC, and connect the ground lead on the scope to pin 4 in the DLC or to a good chassis ground. Adjust the scope voltage setting to 5V and set the time base setting to 100 milliseconds (ms). With the ignition switch on, a normal network should display a voltage pattern as illustrated in Figure 8-32. A **splice pack** is used in the network on some vehicles. A parts locator manual will help the technician to locate the splice pack. This splice pack may be disconnected to isolate the PCM and truck body computer (TBC) from the rest of the network so the network cannot affect these computers. If the vehicle has a no-start condition, and the engine starts after the splice pack is disconnected, the defect is located in the network. Under this condition, the network may be shorted to ground, the network may be shorted to a 12V source, or a module connected to the network may be shorted internally. The network modules may be disconnected one at a time. If the defect is corrected when one module is disconnected, the network problem is in that module. When none of the modules are causing the network problem, voltage and/or ohmmeter tests must be performed on the network wires to locate the shorted condition.

A **splice pack** is a special connector that may be disconnected to isolate specific components when diagnosing vehicle networks.

The Standard Corporate Protocol (SCP) network is used on many vehicles. The two wires in the SCP system are designated as Bus+ and Bus–. Bus+ is connected to pin 2 in the DLC, and Bus– is connected to pin 10 in the DLC. The network voltages at rest with no communication are 5 V on Bus+, and 0 V–.2 V on Bus–. A DVOM may be used to read these voltages. To read the SCP voltages on a lab scope, connect the Channel 1 lead on the lab scope to pin 2 on the DLC, and connect the Channel 2 lead on the lab scope to pin 10 on the DLC. Connect the ground lead to pin 4 on the DLC or a good chassis ground. When the ignition switch is turned on, the normal SCP pattern shown in Figure 8-33 should be displayed. If one network signal is displayed as a flat line, communication has failed between some of the computers

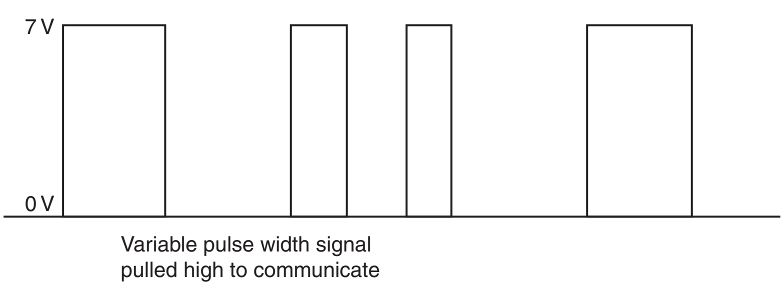

FIGURE 8-32 **Class 2 network voltage signal.**

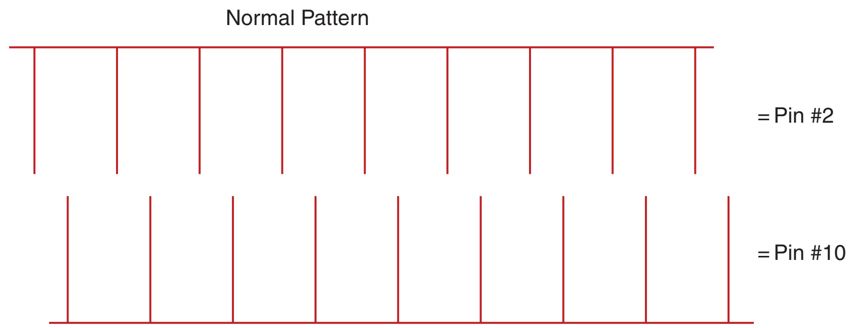

FIGURE 8-33 **SCP network voltage signal.**

and part of the network (Figure 8-34). When both network signals are displayed as a flat line, no communication is taking place through the network. Some networks remain functional with the ignition switch off, because certain module(s) require information under this condition. Always consult the vehicle manufacturer's specific diagnostic information when diagnosing networks.

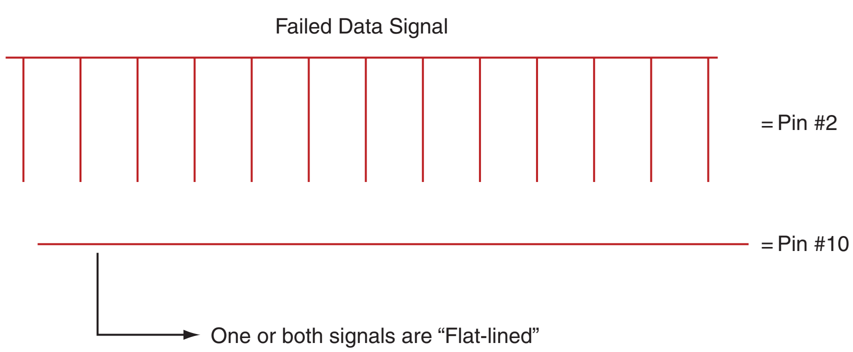

FIGURE 8-34 **SCP network defective voltage signal.**

CASE STUDY

A 2002 GM 1500 series truck was towed into the shop with a no-start condition. During a preliminary diagnosis, the technician discovered there was 12 V on the Class 2 vehicle network with the ignition switched on. The technician used a parts locator manual to locate the splice pack behind the radio. When the splice pack was disconnected, the engine started and ran normally. This proved that the PCM and TBC were not causing the problem, because disconnecting the splice pack isolated these computers from the network. Therefore, the defect must be in the Class 2 network or computers connected in the network. The technician decided to disconnect each computer in the network beginning with the radio/CD player. When the splice pack was reconnected, and the radio disconnected, network voltage was normal, and the engine started and ran normally. Closer internal examination of the radio/CD player indicated a dime lodged between the radio/CD player circuit board and the case. When the dime was removed and the radio reconnected, network voltage and engine operation were normal. The technician used a scan tool to erase all DTCs in the computer memories.

CASE STUDY

A customer brought a 2004 Silverado into the shop with multiple electric problems. The cruise control would cancel when the turn signals were turned on. This only occurred at night when the headlights were on. The customer said several instrument panel readings were randomly intermittent. When a scan tool was connected to the DLC, a U1041 was displayed indicating loss of electronic brake control module (EBCM) data on the network. The technician checked for service bulletins related to this problem and discovered this problem was detailed in a service bulletin. The bulletin indicated this problem was caused by high resistance in ground connection G110 on the vehicle frame below the driver's door. The ground connection was cleaned and tightened and the DTC erased, but the DTC reset again in a short time.

The technician considered the possibility of a defective EBCM. Prior to EBCM replacement, the technician checked the EBCM voltage supply and ground. The EBCM voltage supply was 12 V. When a pair of voltmeter leads was connected from the EBCM ground terminal to the battery ground, the voltmeter indicated 3V. The technician inspected all the wiring from the EBCM module to the battery, and discovered that the battery ground cable was connected to the radiator support rather than being connected to the specified location on the left front corner of the vehicle frame. The battery ground cable and the vehicle frame attaching location were thoroughly cleaned, and the ground cable was properly tightened. Now the voltage reading from the EBCM ground terminal to the battery ground was .2 V. All DTCs were erased with a scan tool, and after driving the vehicle on a road test the DTCs did not reset. All electronic systems operated normally during the road test.

CASE STUDY

A customer complained about the SERVICE RIDE CONTROL light being illuminated on his 2009 Cadillac XLR. When the technician visually inspected the ESC system, no defects were evident. During a diagnostic system check, the scan tool displayed DTC C0577. The detailed DTC explanation in the vehicle manufacturer's service manual indicated this DTC represented a short to ground in the L/F shock absorber damper solenoid circuit.

When the technician disconnected the wiring connector from the L/F damper solenoid and measured the solenoid resistance with an ohmmeter, he discovered the solenoid had the specified resistance of 2.0 ohms.

The technician disconnected the wiring connectors from the ESC module and identified the L/F damper solenoid wires connected to the module. When the technician connected a pair of ohmmeter leads across the wires from the ESC module terminals to the L/F damper solenoid terminals, each wire had very low resistance. Next the technician connected the ohmmeter leads from each terminal in the L/F damper solenoid connector to the ground. When connected to one of the damper solenoid terminals, the ohmmeter displayed an infinite reading indicating the wire was not grounded. However, when the ohmmeter leads were connected from the other damper solenoid terminal to the ground, the ohmmeter indicated a very low reading indicating contact between this wire and the chassis.

A closer examination of the L/F damper solenoid wires indicated these wires were jammed against the chassis about 2 ft. from the damper solenoid. The insulation was worn on the wires, and one wire was contacting the chassis. The technician repaired the wiring insulation and re-positioned the harness so the wires were not jammed against the chassis. The technician used the scan tool to clear the DTC from the ESC module, and road tested the car to be sure the DTC did not reset and illuminate the SERVICE RIDE CONTROL light.

Terms to Know

Antilock brake system (ABS)
Brake pressure modulator valve (BPMV)
Continuously variable road sensing suspension (CVRSS)
Data link connector (DLC)
Diagnostic trouble codes (DTCs)
Electronic brake and traction control module (EBTCM)
Electronic suspension control (ESC)
OBD II computer systems
Programmed ride control (PRC)
Powertrain control module (PCM)
Scan tool
Splice pack
Stabilitrak®
Trim height
Vehicle dynamic suspension (VDS)

ASE-Style Review Questions

1. When performing a self-test on a programmed ride control system:
   A. The mode select switch must be in the Auto position.
   B. One of the wires in the self-test connector must be grounded.
   C. The engine must be off and the ignition switch turned on.
   D. The headlights must be on during the self-test.

2. When servicing a vehicle with an air suspension system, the air suspension switch must be turned off:
   A. When changing the engine oil and filter.
   B. When changing the spark plugs.
   C. When jacking the vehicle to change a tire.
   D. During any of the above service procedures.

3. To deflate an air spring prior to removal of the spring:
   A. Disconnect the air line from the air spring.
   B. Turn the air spring solenoid valve to the first stage.
   C. Turn the air spring solenoid valve to the second stage.
   D. Energize the vent solenoid in the air compressor.

4. When using the scan tool to inflate an air spring:
   A. The vehicle must be raised on a tire-contact lift.
   B. The scan tool commands the air compressor on.
   C. The air suspension switch must be on.
   D. The scan tool commands the vent solenoid on.

5. When using a scan tool to perform a ride height adjustment on a vehicle dynamic suspension (VDS),

   Technician A says the VDS switch must be in the Off position.

   Technician B says if the ride height does not equal the manufacturer's specifications, the scan tool is used to command the VDS to lower or lift the vehicle to obtain the specified ride height.

   Who is correct?
   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

6. All of these statements about performing an on-demand self-test on a VDS system are true EXCEPT:
   A. The battery must be fully charged.
   B. The ignition switch must be on.
   C. The vehicle must be raised on a lift.
   D. The 4L mode must not be selected on four-wheel-drive vehicles.

7. When diagnosing a VDS system, a U1900 DTC is obtained. This DTC indicates a defect in the:
   A. Controller area network (CAN).
   B. L/R air spring solenoid.
   C. Vent solenoid.
   D. R/F height sensor.

8. When diagnosing an electronic suspension control (ESC) system,

   Technician A says defects represented by a DTC with a U prefix must be repaired before proceeding with further diagnosis or service.

   Technician B says ESC system operation may be affected by low battery voltage.

   Who is correct?
   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

9. On an ESC system a normal voltage signal from a wheel position sensor is:
   A. 2.5 V.
   B. 5.5 V.
   C. 6.1 V.
   D. 6.8 V.

10. While discussing ESC system diagnosis,

    Technician A says the normal force signal on a scan tool indicates a measured level of road surface condition sent from the ESC module to the EBCM.

    Technician B says the normal force data is sent from the front and rear wheels.

    Who is correct?
    A. A only
    B. B only
    C. Both A and B
    D. Neither A nor B

ASE Challenge Questions

1. *Technician A* says during air spring inflation the vehicle weight must be applied to the suspension system.

   Technician B says during air spring inflation the vehicle should be positioned on a lift so the wheels are dropped downward.

   Who is correct?

   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

2. All of these statements about a programmed ride control system are true EXCEPT:

   A. An air spring is mounted at each corner of the vehicle.
   B. An electric actuator is located in each strut.
   C. A mode indicator light is positioned in the tachometer.
   D. The PRC module provides a firm ride during severe braking.

3. *Technician A* says the suspension switch must be turned off before raising any corner of a car with an electronic air suspension.

   Technician B says the ignition switch must not be turned on while any corner of a car with electronic air suspension is raised.

   Who is correct?

   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

4. A vehicle with an electronic air suspension system with mechanical trim height adjustment requires front and rear trim height adjustment.

   Technician A says to adjust the front trim height, rotate the threaded mounting bolt in the upper end of the height sensor.

   Technician B says to adjust the rear trim height, loosen the attaching bolt(s) on the upper height sensor bracket and move the bracket upward or downward.

   Who is correct?

   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

5. When removing and replacing an air spring and shock absorber assembly on a VDS:

   A. The self-locking nuts on the upper strut mount can be reused.
   B. Retainer tabs on the lower end of the spring must be depressed to separate the spring and the shock absorber.
   C. The spring must be vented by loosening the spring solenoid valve to the first stage.
   D. The VDS switch and the ignition switch must be in the On position.

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Name ______________________________________ Date ________________________

Inspection and Preliminary Diagnosis of Computer-Controlled Suspension System

Upon completion of this job sheet, you should be able to inspect computer-controlled suspension systems.

NATEF Correlation

This job sheet is correlated with NATEF Automotive Suspension and Steering Task D-3: Test and diagnose components of electronically controlled suspension systems using a scan tool; determine necessary action.

Tools and Materials

Modern vehicle with electronically controlled suspension system.

Describe the Vehicle Being Worked On

Year ____________ Make __________________ Model _______________________________

VIN _______________________________ Engine type and size ________________________

Procedure

Task Completed

1. Discuss the vehicle complaint with the customer.

   Describe the customer complaint(s). ____

   ____

   ____

2. Road test the vehicle and verify the vehicle complaint. ☐

   Describe the vehicle complaint experienced during the road test.

   ____

   ____

   ____

3. Inspect the vehicle for collision damage or other damage that could affect the computer-controlled suspension system. ☐

   Describe any collision or other vehicle damage that could affect the computer-controlled suspension system ____

   ____

   ____

4. Inspect all electrical connections and wiring harness in the suspension system. ☐

   Wiring connection and harness condition, Satisfactory ☐ Unsatisfactory ☐

Task Completed

If the wiring connection and harness condition are unsatisfactory, explain the wiring connection and/or harness defects.

____

____

5. If the vehicle has an air suspension system, listen for air leaks near the air-operated components and air lines, and inspect all the air lines for cracks, breaks, damage, and kinks.

   Air line condition, Satisfactory ☐ Unsatisfactory ☐

   If the air line condition is unsatisfactory, explain the air line defects.

   ____

   ____

   ____

6. Measure the vehicle ride (trim) height.

   Ride height, L/F __________, R/F __________, L/R __________, R/R __________

   Specified ride height, Front __________ Rear __________

7. Observe the operation of the suspension warning light or message display in the instrument panel.

8. Suspension warning light or message display operation,
   Normal ☐ Abnormal ☐

9. Based on your inspection and preliminary diagnosis of the computer-controlled suspension system, list the problems in the system and explain the required further diagnostic and service procedures.

   ____

   ____

   ____

   ____

Instructor's Response ____

____

____

Name ______________________________ Date ____________________

Adjust Vehicle Ride (Trim) Height with a Scan Tool

Upon completion of this job sheet, you should be able to adjust the vehicle ride height with a scan tool on computer-controlled suspension systems.

NATEF Correlation

This job sheet is correlated with NATEF Automotive Suspension and Steering Task D-3: Test and diagnose components of electronically controlled suspension systems using a scan tool; determine necessary action.

Tools and Materials

Modern vehicle with a vehicle dynamic suspension (VDS) system.
Scan Tool
Tape Measure

Describe the Vehicle Being Worked On

Year ________ Make ________________ Model ________________________
VIN ________________________ Engine type and size ____________________

Procedure

Task Completed

1. Be sure the air suspension switch is in the On position.

   Air suspension switch On, ☐ Yes ☐ No

2. Be sure the battery is fully charged.

   Battery fully charged, ☐ Yes ☐ No

3. Turn off the ignition switch and exit the vehicle. Close all doors and wait 45 seconds for the air suspension system to vent down to the kneel position.

   VDS suspension in the kneel position, ☐ Yes ☐ No

4. Open the driver's door, and turn on the ignition switch.

   Ignition switch on, ☐ Yes ☐ No

5. Shift the transmission into Drive and back into Park.

   Transmission shifted into Drive and back into Park, ☐ Yes ☐ No

6. Exit the vehicle, close all the doors, and wait 45 seconds for the suspension system to pump up to the trim height.

   VDS system in the trim height position, ☐ Yes ☐ No

Task Completed

7. Use a tape measure to measure the ride height at the locations specified by the vehicle manufacturer.

   Specified ride height, Front ____________ Rear ____________

   Actual ride height, L/F __________, R/F __________, L/R __________ R/R ____________

8. If the ride height does not equal the manufacturer's specifications, open the left-front door, and connect the scan tool to the DLC.

   Scan tool properly connected to the DLC, ☐ Yes ☐ No

9. Select the correct vehicle year, model, and engine type on the scan tool, and then select *Vehicle Dynamic Module* (VDM).

   Scan tool selections, Vehicle year ____________ Model ____________

   Engine Size ____________

   Vehicle Dynamic Module (VDM) selected on scan tool,
   ☐ Yes ☐ No

10. Use the active command mode in the scan tool to vent or lift the vehicle to achieve the specified trim height.

    Active command mode on scan tool used to lift or vent VDS system to specified trim height, ☐ Yes ☐ No

11. When a tape measure indicates the specified front and rear ride height, select *Save Calibration Values* on the scan tool to calibrate the VDM to the specified trim height.

    Actual ride height, L/F __________, R/F __________, L/R __________ R/R ____________

Instructor's Response ____

____

____

Name ______________________________ Date ____________________

Perform an On-Demand Self-Test on a Vehicle Dynamic Suspension (VDS) System

Upon completion of this job sheet, you should be able to perform an On-Demand Self-Test on a vehicle dynamic suspension (VDS) system.

NATEF Correlation

This job sheet is correlated with NATEF Automotive Suspension and Steering Task D-3: Test and diagnose components of electronically controlled suspension systems using a scan tool; determine necessary action.

Tools and Materials

Modern vehicle with a vehicle dynamic suspension (VDS) system.
Scan tool

Describe the Vehicle Being Worked On

Year __________ Make ________________ Model ______________________
VIN ________________________ Engine type and size ____________________

Procedure

Task Completed

1. Be sure the transmission is in Park.

   Transmission in Park, ☐ Yes ☐ No

2. Be sure the battery is fully charged.

   Battery fully charged, ☐ Yes ☐ No

3. Connect the scan tool to the DLC.

   Scan tool properly connected to the DLC, ☐ Yes ☐ No

4. Lower the driver's window and close all doors, liftgate, and liftgate glass.

   Driver's window down, ☐ Yes ☐ No

   All doors, liftgate, and liftglass closed, ☐ Yes ☐ No

5. Be sure the 4L mode is not selected on four-wheel-drive models.

   4L switch off, ☐ Yes ☐ No

6. Turn on the ignition switch.

   Ignition switch on, ☐ Yes ☐ No

7. Select *Vehicle Dynamic Module* and *On-Demand Self-Test* on the scan tool.

   Vehicle Dynamic Module selected on scan tool, ☐ Yes ☐ No

   On-Demand Self-Test selected on scan tool, ☐ Yes ☐ No

Task Completed

8. Record all the DTCs displayed on the scan tool.

____

____

____

9. Use the vehicle manufacturer's service information to interpret the meaning of each DTC, and list the meaning of each DTC in the spaces below.

____

____

____

10. Turn off the ignition switch, and disconnect the scan tool.

Ignition switch OFF, ☐ Yes ☐ No

Scan tool disconnected, ☐ Yes ☐ No

Instructor's Response ____

____

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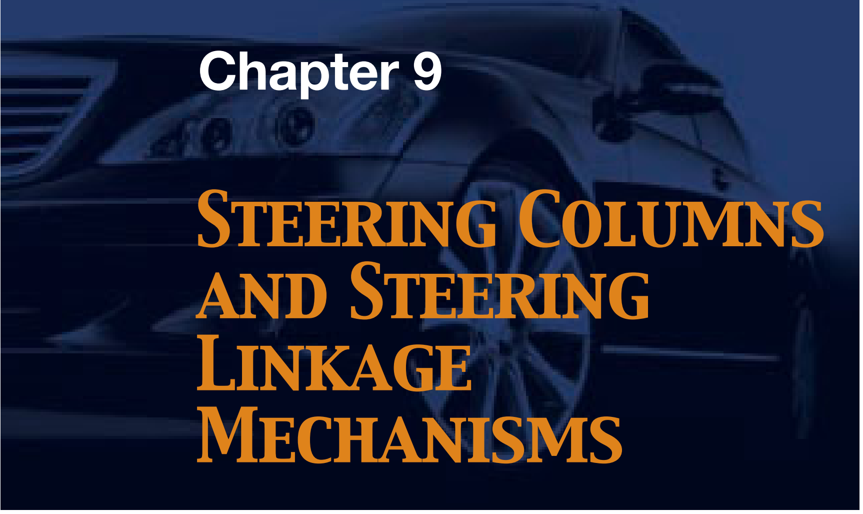

Chapter 9

Steering Columns and Steering Linkage Mechanisms

Upon completion and review of this chapter, you should be able to understand and describe:

- How the steering column provides driver safety during a frontal collision.
- Two methods of steering column movement to protect the driver in a frontal collision.
- The purpose of a clock spring electrical connector.
- The mechanism that locks the steering wheel and gear shift when the ignition switch is in the lock position.
- A parallelogram steering linkage and explain the advantage of this type of linkage.
- The components in a parallelogram steering linkage.
- The purposes of the pitman arm and the idler arm.
- Two possible rack and pinion steering gear mountings.
- The rack and pinion steering linkage, and explain the advantages of this type of linkage.
- The design and operation of an active steering column.
- The design and operation of a driver protection module.

Introduction

Steering columns play a significant part in steering control, safety, and driver convenience. The steering column connects the steering wheel to the steering gear. The column components must be in satisfactory condition to minimize free play and to provide adequate steering control. If steering column components such as universal joints are worn, column free play is excessive and steering control is reduced.

Most steering columns provide some method of column collapse during a collision. Some vehicles have plastic pins that shear off in the column jacket, gearshift tube, and steering shaft if the driver hits the steering wheel in a frontal collision. This shearing action of the plastic pins allows the column to collapse away from the driver. In other vehicles, the column-to-instrument-panel mounting is designed to allow column movement if the driver hits the steering wheel in a collision. This action helps prevent driver injury.

All air-bag-equipped vehicles have a driver's side air bag located in the upper side of the steering wheel, and most vehicles also have a passenger's side air bag mounted in the instrument panel. Some vehicles now have seat belt pretensioners that tighten the seat belts and

hold the driver or passengers back against the seat if the vehicle is involved in a collision. Many vehicles now have side air bags mounted in the outer edge of the seat back, or an air bag curtain mounted just above the front and rear door openings. The side air bags have a separate module and sensors, and deploy only when the vehicle is involved in a side collision.

A recent development on some vehicles is the installation of **pre-safe systems** that react during the few milliseconds before a collision occurs to increase driver and passenger safety. The input signals to the pre-safe system include vehicle speed, braking torque, brake pedal application speed, wheel slip, vehicle acceleration around the vertical axis, spring compression and rebound travel, steering wheel rotational speed, and tire pressure. The pre-safe system recognizes and acts in three crucial situations:

1. Sideways skidding
2. Avoidance maneuvers
3. Emergency braking beyond ABS operation

The pre-safe system can differentiate between a drama and a crisis. For example, if the vehicle is driven over a patch of ice and the brakes are applied lightly without any vehicle skidding, the ABS system can operate to prevent wheel lockup, but the pre-safe system recognizes this condition as a drama and remains inoperative. The pre-safe system also remains inoperative during mild avoidance maneuvers.

When the inputs indicate an impending crisis driving situation, the pre-safe system performs these functions:

1. Pretensions the driver and front passenger seat belts so the driver and front passenger are optimally restrained in their seats during emergency braking or a skid prior to a collision. When a collision occurs, pyrotechnic seat belt tensioners provide increased seat belt tension. If a collision does not occur, the seat belts return to normal tension.
2. If the front passenger seat is moved too far forward, the pre-safe system moves the seat rearward before a collision occurs. If appropriate, the front passenger seat cushion and backrest are moved to a position that provides increased passenger protection if a collision occurs. For example, a steeply inclined seat backrest or a flat seat cushion may impair passenger restraint during a collision.
3. The electronically adjustable, individual rear seat cushions are moved to the best possible angle to improve rear passenger restraint.
4. The sliding sunroof is closed to reduce the risk of occupant injury if a rollover occurs.

The brake assist system (BAS) also plays a crucial role in the pre-safe system operation. The BAS system operates beyond the ABS and electronic stability program (ESP) parameters. If the BAS detects an unstable driving condition such as severe vehicle skidding, it uses brake intervention and engine power reduction to correct the situation.

When the vehicle is involved in a frontal collision above a specific speed, the air bag sensor signals deploy the air bag or bags in a few milliseconds. As the driver is thrust forward during the frontal collision, the inflated air bag prevents the driver from striking the steering wheel, windshield, or instrument panel. The air bag deflates very quickly so it does not block the driver's vision in case the driver is still attempting to steer the vehicle. Since the driver's side air bag and some connecting components are mounted in the steering column, this column is a very important part of the vehicle safety equipment.

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Steering columns may be classified as nontilting, tilting, and tilting/telescoping. Tilt steering columns facilitate driver entry to and exit from the front seat. These columns also allow the driver to position the steering wheel to suit individual comfort requirements (Figure 9-1). A tilting/telescoping steering column allows the driver to tilt and extend or retract the steering wheel. In this type of steering column, the driver has more steering wheel position choices.

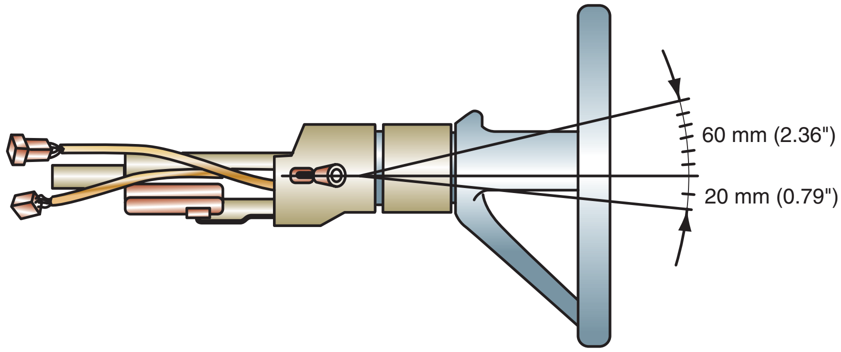

FIGURE 9-1 Tilt steering column.

The **toe plate** surrounds the steering column and covers the opening where the column extends through the vehicle floor.

The **silencer** is mounted with the toe plate and helps to reduce the transmission of engine noise to the passenger compartment.

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Chapter 9, page 300

Conventional Nontilt Steering Column

Design

Many steering columns contain a two-piece steering shaft connected by two universal joints. A jacket and shroud surround the steering shaft. The upper shaft is supported by two bearings in the jacket. A **toe plate**, seal, and **silencer** surround the lower steering shaft and cover the opening where the shaft extends through the floor (Figure 9-2). The lower steering shaft is surrounded by a shield underneath the toe plate.

The lower universal joint couples the lower shaft to the stub shaft in the steering gear. In some steering columns, a flexible coupling is used in place of the lower universal joint (Figure 9-3).

Studs and nuts retain the steering column bracket to the instrument panel support bracket. The steering column is designed to protect the driver if the vehicle is involved in a frontal collision. An **energy-absorbing lower bracket** and lower plastic adapter are used to connect the steering column to the instrument panel mounting bracket. This bracket allows the column to slide down if the driver is thrown forward into the wheel in a frontal collision. The mounting bracket is also designed to prevent rearward movement toward the driver in a collision.

In some steering columns, the outer column jacket is a two-piece unit retained with plastic pins (Figure 9-4). In this type of column, the lower steering shaft is also a two-piece sliding unit retained with plastic pins (Figure 9-5). When the driver is thrown against the steering wheel in a frontal collision, the plastic pins shear off in the lower steering shaft and outer

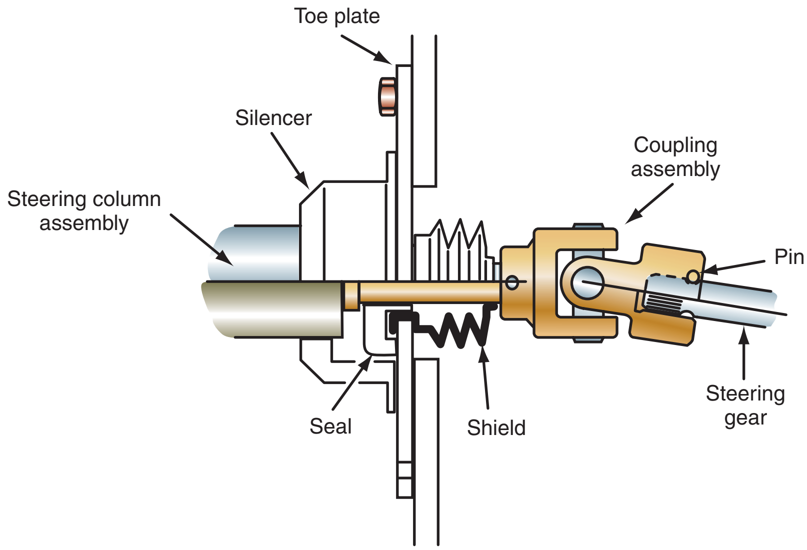

FIGURE 9-2 Toe plate and silencer.

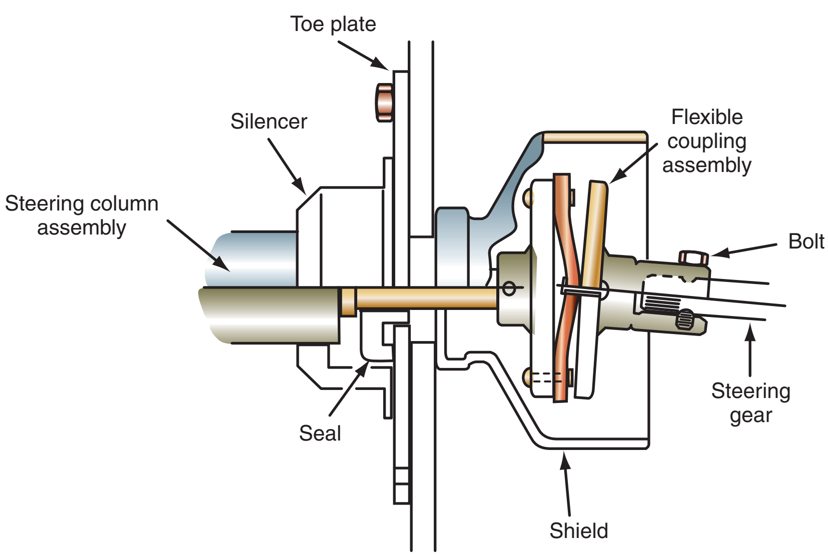

FIGURE 9-3 **Flexible coupling.**

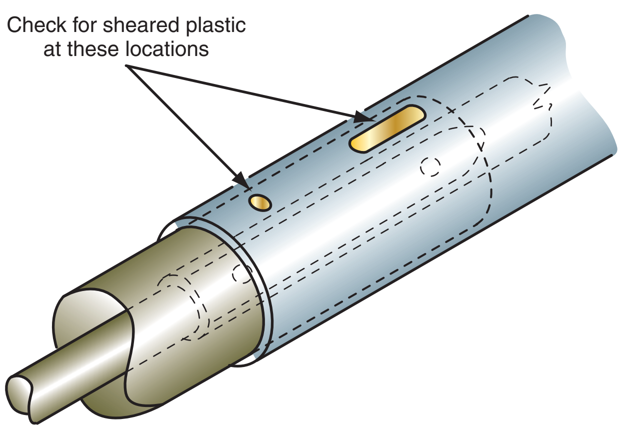

FIGURE 9-4 **Injection plastic in collapsible outer steering column jacket.**

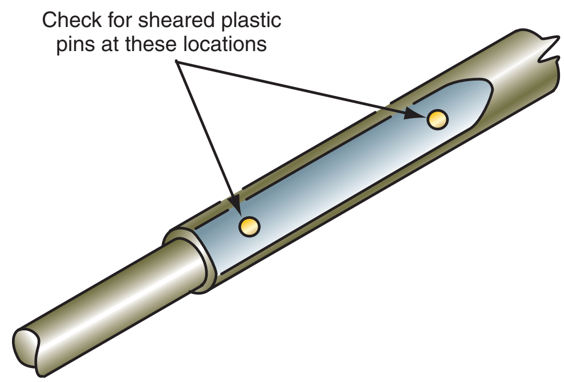

FIGURE 9-5 **Injection plastic in collapsible lower steering shaft.**

column jacket. The shearing action of the plastic pins allows the steering column to collapse away from the driver, which reduces the impact as the driver hits the steering wheel.

A few current vehicles have steering columns with magnesium jackets or housings to reduce vehicle weight. Vehicle weight reduction improves fuel economy and reduces emissions.

An adaptive steering column has recently been introduced to the automotive market on some new models. The adaptive steering column collapses at two different speeds based on information received about the driver. Many vehicles now have sensors in the lower part of a front seat to determine the weight of the driver and the weight and the presence of a passenger. The driver's weight signal, and other input signals are used by the restraints control module (RCM) to vary the air bag deployment force. The driver's weight input signal also determines how quickly the steering column should collapse. The adaptive steering column tailors the steering column collapse load to the driver's mass, safety belt use, and seat track position.

An adaptive steering column contains an energy-absorbing steel that buckles between the upper and lower portions of the steering column. The RCM receives input signals from various crash sensors indicating the severity of the crash, and this module determines the speed of steering column collapse. If the input signals indicate a faster steering column collapse is

A **pyrotechnic** device contains an explosive and an ignition source.

An **air bag deployment module** contains the air bag and the inflator device.

CAUTION: When servicing a vehicle equipped with an air bag or bags, follow all service precautions in the vehicle manufacturer's service manual. Failure to follow these precautions may result in an expensive, accidental air bag deployment.

The clock spring maintains positive electrical contact between the air bag module and the air bag electrical system regardless of steering wheel position. A clock spring electrical connector may be called a coil, **spiral cable**, or cable reel, depending on the manufacturer.

The combination turn signal, hazard warning, wipe/wash, and dimmer switch is sometimes called a smart switch.

required, the RCM fires a **pyrotechnic** device in the steering column that pulls a pin in the column and allows the energy-absorbing steel to buckle and provide faster column collapse. The result is a softer impact between the driver and the steering wheel. The adaptive steering column is designed to operate with the driver's air bag.

When the driver is thrown against the steering wheel during a collision, many steering wheels are designed to deform away from the driver to reduce the force on the driver's body.

WARNING: Small amounts of sodium hydroxide are a by-product of an air bag deployment. Sodium hydroxide is a caustic chemical that causes skin irritation and eye damage. Always wear eye protection and gloves when servicing and handling a deployed air bag.

On many cars, the **air bag deployment module** is mounted in the top of the steering wheel (Figure 9-6). A **clock spring electrical connector**, or **spiral cable**, is mounted under the steering wheel. This component contains a ribbon-type conductor that maintains constant electrical contact between the air bag module and the air bag electrical system during steering wheel rotation.

The steering wheel splines fit on matching splines on the top of the upper steering shaft, and a nut retains the wheel on the shaft. Most steering wheels and shafts have matching alignment marks that must be aligned when the steering wheel is installed.

An ignition switch cylinder is usually mounted in the upper right side of the column housing, and the ignition switch is bolted on the lower side of the housing (Figure 9-7). An operating rod connects the ignition switch cylinder to the ignition switch. Ignition switches are integral with the lock cylinder in some steering columns.

The turn signal switch and hazard warning switch are mounted on top of the steering column under the steering wheel. Lugs on the bottom of the steering wheel are used to cancel the signal lights after a turn is completed. On many vehicles, the signal light lever also operates the wipe/wash switch and the dimmer switch (Figure 9-8).

If the gear shift is mounted in the steering column, a tube extends from the gear shift housing to the shift lever at the lower end of the steering column. This shift lever is connected through a linkage to the transaxle or transmission shift lever. A lock plate is attached to the upper steering shaft, and a lever engages the slots in this plate to lock the steering wheel and gear shift when the gear shift is in Park and the ignition switch is in the Lock position (Figure 9-9).

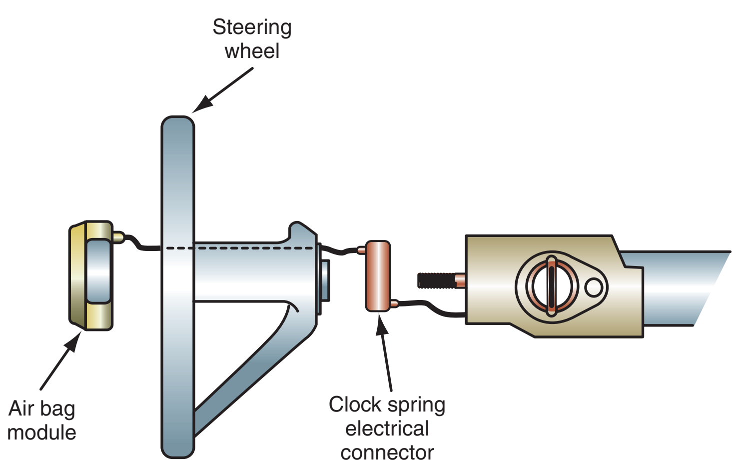

FIGURE 9-6 **Air bag inflator module mounted in the steering wheel and clock spring electrical connector located under the steering wheel.**

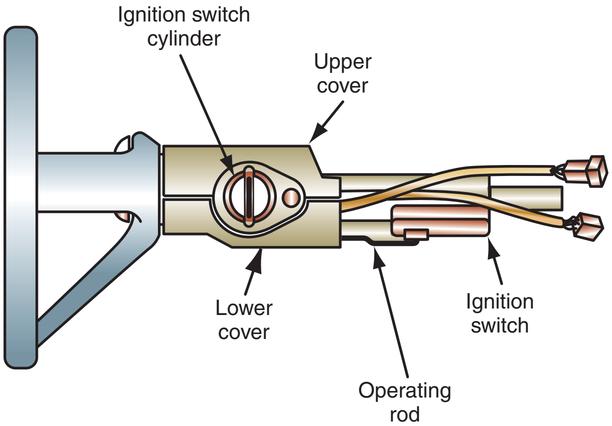

FIGURE 9-7 **Ignition switch and ignition switch cylinder mounted in steering column.**

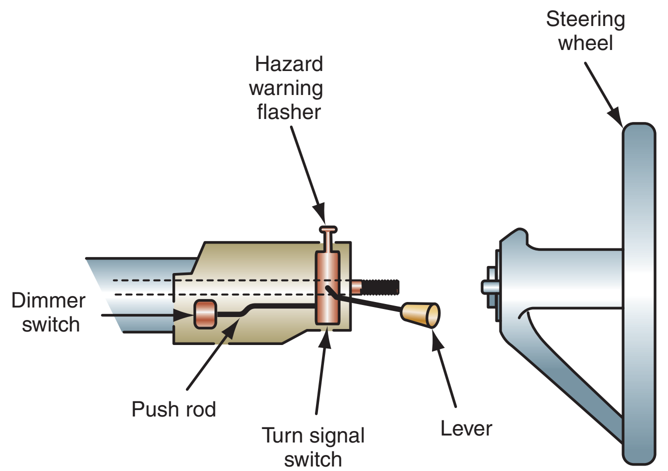

FIGURE 9-8 **Turn signal switch, hazard warning switch, dimmer switch, and wipe/wash switch mounted in steering column.**

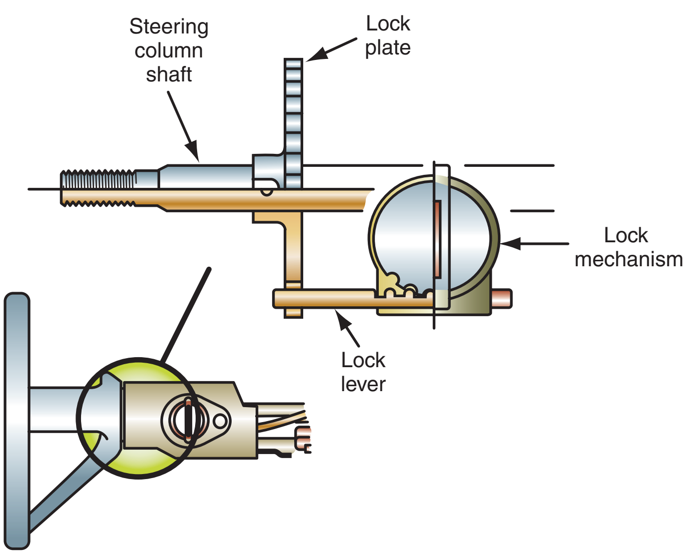

FIGURE 9-9 **Upper steering column with locking plate and lever.**

Tilt Steering Column

Design

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Tilt steering columns have a short upper steering shaft connected to the steering wheel in the usual manner. This upper steering shaft is connected through a universal joint to the lower steering main shaft. An upper column tube surrounds the upper steering shaft, and the lower steering main shaft is supported on bushings in the lower column tube (Figure 9-10).

When the steering wheel is tilted, the wheel and upper steering column tube pivot on two bolts connected between the upper and lower column tubes. During the steering wheel tilting motion, the upper steering shaft pivots on the universal joint connected between the upper steering shaft and the lower steering main shaft. A release lever on the side of the steering column must be activated to allow the wheel and upper column to tilt. This steering wheel action allows the driver to position the steering wheel for greater comfort and easier movement in and out of the driver's seat.

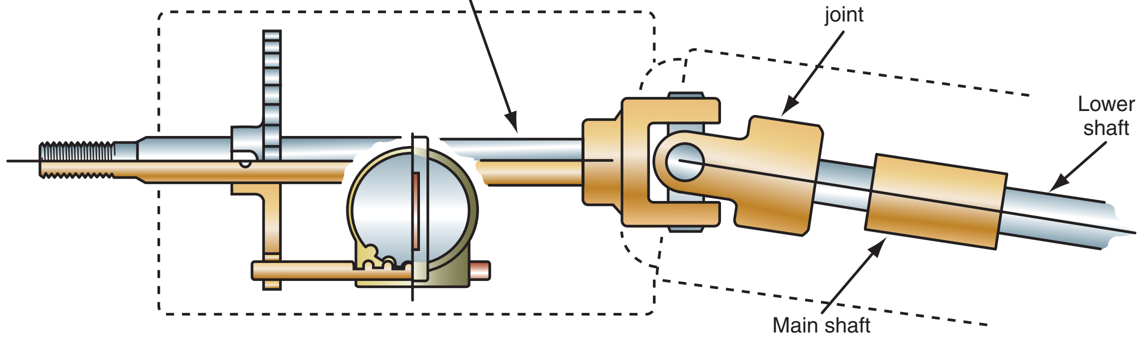

FIGURE 9-10 **Tilt steering column components.**

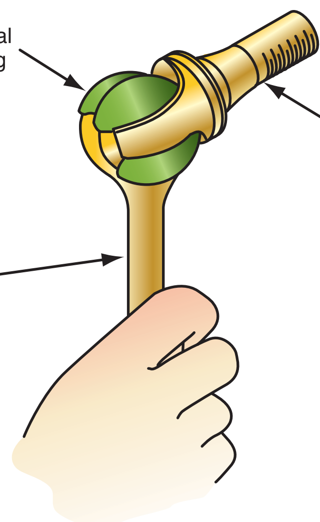

FIGURE 9-11 **Spherical bearing acts as a pivot between the upper steering shaft and the lower steering main shaft in some tilt steering columns.**

In some steering columns, a **spherical bearing** acts as a pivot between the upper steering shaft and the lower steering main shaft (Figure 9-11).

Four bolts attach the lower column support tube to the instrument panel. The ignition lock cylinder and switch are mounted in an upper bracket that is clamped to the lower column tube. A universal joint is connected between the lower steering mainshaft and the intermediate shaft assembly, which is attached to the stub shaft on the steering gear (Figure 9-12).

A steering wheel pad containing the air bag deployment module is mounted in the top of the steering wheel. Electrical contact between the air bag deployment module and the air bag electrical system is maintained by a clock spring electrical connector, or spiral cable, mounted directly under the steering wheel (Figure 9-13). A combination switch is mounted directly under the clock spring electrical connector. This switch contains the signal light switch, hazard light switch, dimmer switch, and wipe/wash switch. The upper side of the steering wheel also contains the horn switch contacts.

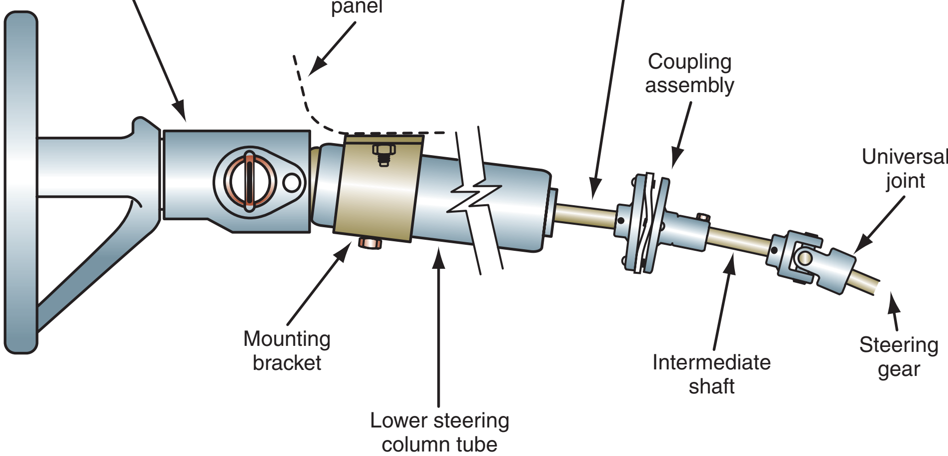

FIGURE 9-12 **Tilt steering column with universal joint, intermediate shaft, combination switch, and steering wheel.**

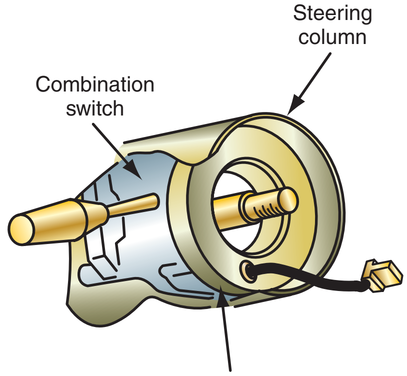

FIGURE 9-13 **Clock spring electrical connector, or spiral cable, maintains electrical contact between the air bag inflator module and the air bag electrical system.**

Electronic Tilt/Telescoping Steering Column

Some vehicles are equipped with an electronically controlled tilt/telescoping steering column. A driver-operated switch mounted in the steering column below the signal light lever controls the tilt/telescoping functions (Figure 9-14). A tilt/telescoping motor is mounted in the steering column power assembly (Figure 9-15). A potentiometer is mounted on the side of the tilt/telescoping motor, and this potentiometer is a steering column position sensor (Figure 9-15). This potentiometer sends a voltage signal to the driver position module (DPM) in relation to the motor and steering wheel position. The steering column position sensor signal is sent to the DPM, and the DPM uses this signal when storing and recalling steering column memory settings. A short tilt cable assembly is connected between the tilt/telescoping motor and the tilt mechanism in the steering column (Figure 9-16).

When the tilt/telescoping switch is operated by the driver, it sends voltage input signals to the DPM. If the driver operates the tilt/telescoping switch to request the telescoping

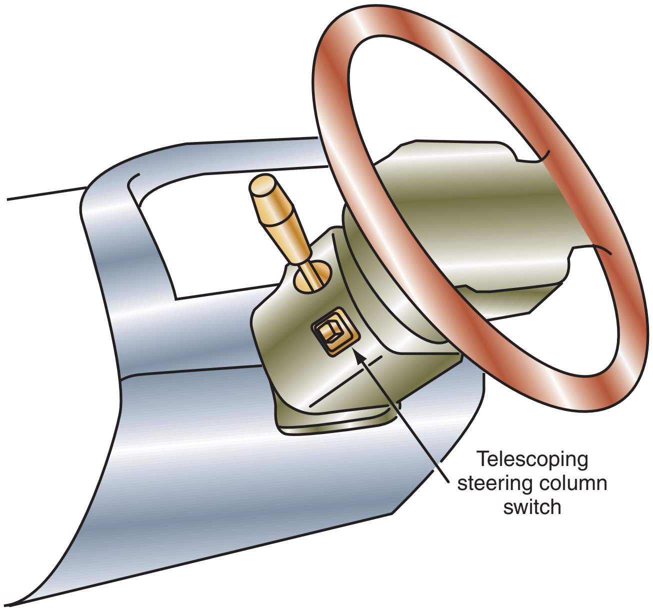

FIGURE 9-14 Tilt/telescoping steering column switch.

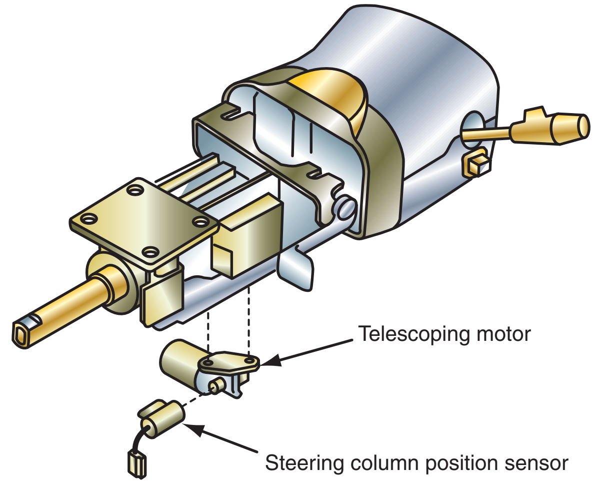

FIGURE 9-15 Tilt/telescoping motor and steering column position sensor.

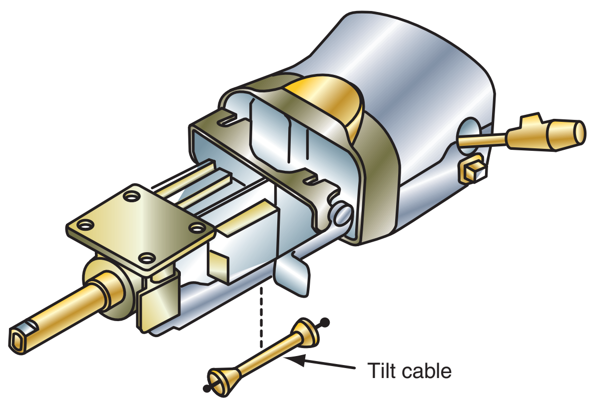

FIGURE 9-16 Tilt cable for tilt/telescoping steering column.

function, the DPM operates the tilt/telescoping motor to move the steering wheel toward or away from the driver depending on the switch request. When the driver operates the tilt/telescoping switch to request the tilt function, the DPM operates the tilt/telescoping motor to tilt the wheel upward or downward depending on the switch request. The DPM is interconnected via data links to some of the other on-board computers. Therefore, the DPM can receive input signals from other computers such as the driver door switch (DDS) module via the data links. When the ignition switch is turned off and the driver pushes the unlock button on the driver's door, the DPM tilts the steering column to a position that allows easier exit from the driver's seat. When the driver enters the vehicle and turns on the ignition switch, the DPM moves the steering column back to the previous setting.

Active Steering Column

The active steering column in some vehicles actively adjusts the energy-absorbing capability of the steering column using a pyrotechnic actuator. This type of steering column has a section of energy-absorbing steel that holds the upper and lower halves of the steering column

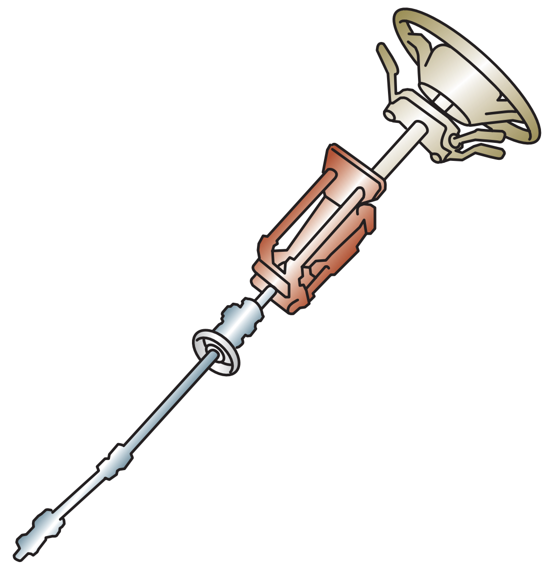

FIGURE 9-17 **Active steering column.**

together (Figure 9-17). The energy-absorbing steel section is designed to control the collapse of the steering column during impacts.

A restraints control module (RCM) operates a pyrotechnic actuator in the steering column. Input sensors inform the RCM regarding driver weight, front seat position, driver seat belt usage, and crash severity. When the RCM receives input signals indicating softer steering column collapse is necessary to protect the driver, the RCM fires the pyrotechnic device in the steering column. This action pulls a pin out of the column, and reduces the columns' resistance to collapse. The steering column collapse is designed to operate with the air bag level that is being activated. The ease of steering column collapse is different for a belted or unbelted driver. The active steering column helps the vehicle manufacturers to meet enhanced federal safety regulations that now require crash protection for 5th percentile, smaller female drivers, and 50th percentile, large male drivers with and without seat belts.

Driver Protection Module

In the driver protection module, the steering column, knee bolster, and pedals are mounted in a module that allows these components to move away from the driver in a controlled manner during a vehicle crash (Figure 9-18). The driver protection module contains steel tubes

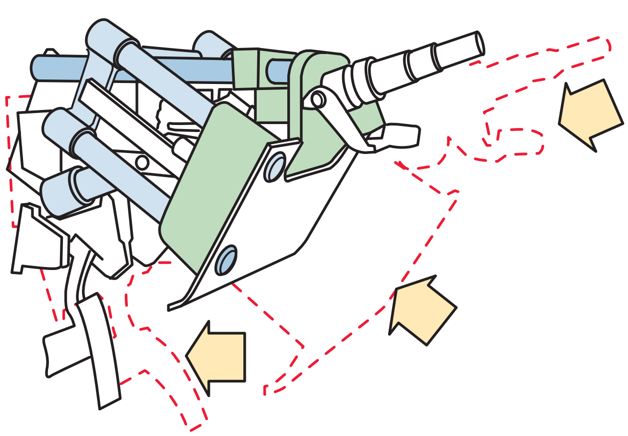

FIGURE 9-18 **Driver protection module.**

supported by aluminum extrusions. This design allows the steering column, knee bolster, and pedals to move along the trajectory of the driver during a severe vehicle crash. This action helps to maintain air bag position. The driver protection module will be introduced on some 2009 vehicles, and some final design changes may be incorporated in the module. During a vehicle crash, the driver protection module movement may be controlled actively by a pyrotechnic device operated by an electronic module. The driver protection module will provide adequate crash protection for drivers from the 5th percentile to the 95th percentile. It is expected that this level of protection will be required by federal legislation in the future.

Steering Linkage Mechanisms

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Parallelogram Steering Linkage

Steering linkage mechanisms are used to connect the steering gear to the front wheels. A **parallelogram steering linkage** may be mounted behind the front suspension (Figure 9-19) or in front of the front suspension (Figure 9-20). The parallelogram steering linkage must not interfere with the engine oil pan or chassis components.

A **parallelogram steering linkage** may be defined as one in which the tie-rods are mounted parallel to the lower control arms.

WARNING: Always remember that a customer's life may depend on the condition of the steering linkages on his or her vehicle. State safety inspections play a very important role in maintaining suspension, steering, and other vehicle systems in safe driving condition and saving lives. During undercar service, always make a quick check of the steering linkage condition.

Regardless of the parallelogram steering linkage mounting position, this type of steering linkage contains the same components. The main components in this steering linkage mechanism are:

1. Pitman arm
2. Center link
3. Idler arm assembly
4. Tie-rods with sockets
5. Tie-rod ends

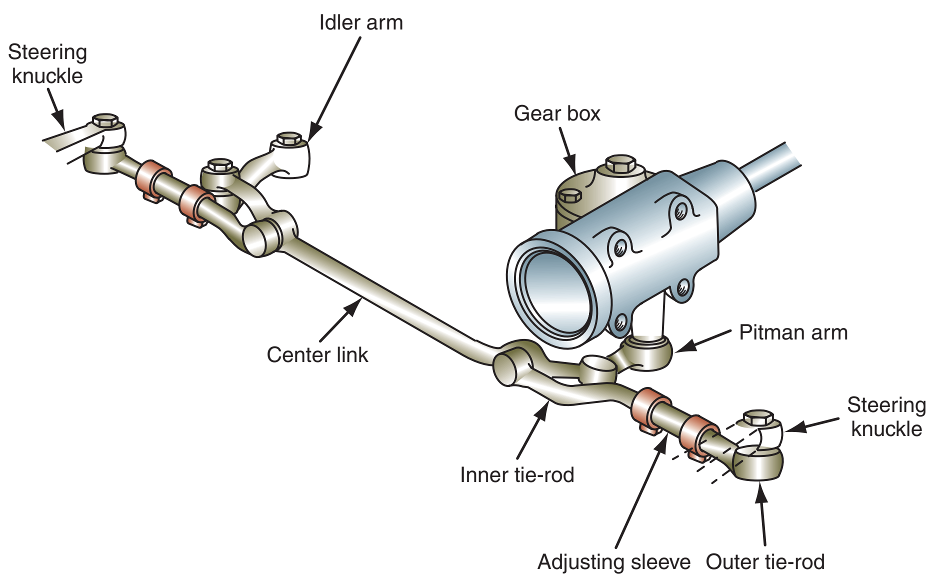


FIGURE 9-19 **Parallelogram steering linkage behind the front suspension.**

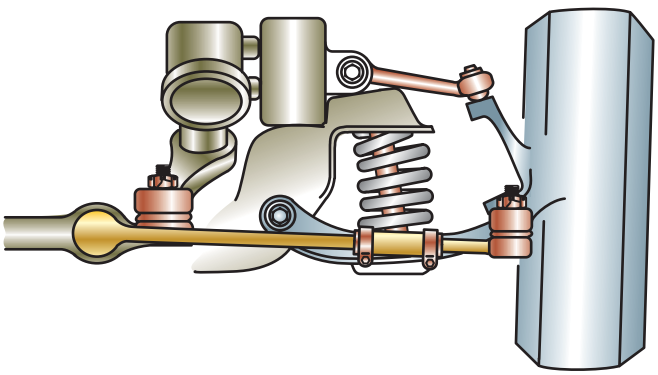


FIGURE 9-20 **Parallelogram steering linkage in front of the front suspension.**

Parallelogram steering linkages are found on independent front suspension systems. In a parallelogram steering linkage, the tie-rods are connected parallel to the lower control arms. Road vibration and shock are transmitted from the tires and wheels to the steering linkage, and these forces tend to wear the linkages and cause steering looseness. If the steering linkage components are worn, steering control is reduced. Since loose steering linkage components cause intermittent toe changes, this problem increases tire wear. The wear points in a parallelogram steering linkage are the tie-rod sockets and ends, idler arm, and center link end.

Tie-Rods

The **tie-rod** assemblies connect the center link to the steering arms, which are bolted to the front steering knuckles. In some front suspensions, the steering arms are part of the steering knuckle; in other front suspension systems, the steering arms are bolted to the knuckle. A ball socket is mounted on the inner end to each tie-rod, and a tapered stud on this socket is mounted in a center link opening. A castellated nut and cotter pin retain the tie-rods to the center link. A threaded sleeve is mounted on the outer end of each tie-rod, and a tie-rod end is threaded into the outer end of this sleeve (Figure 9-21).

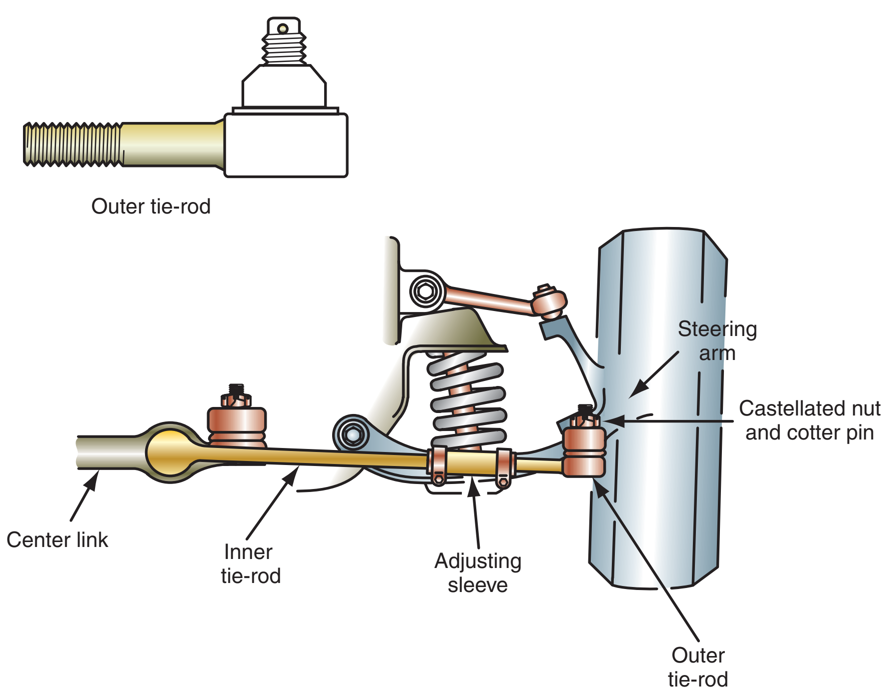


FIGURE 9-21 **Tie-rod design.**

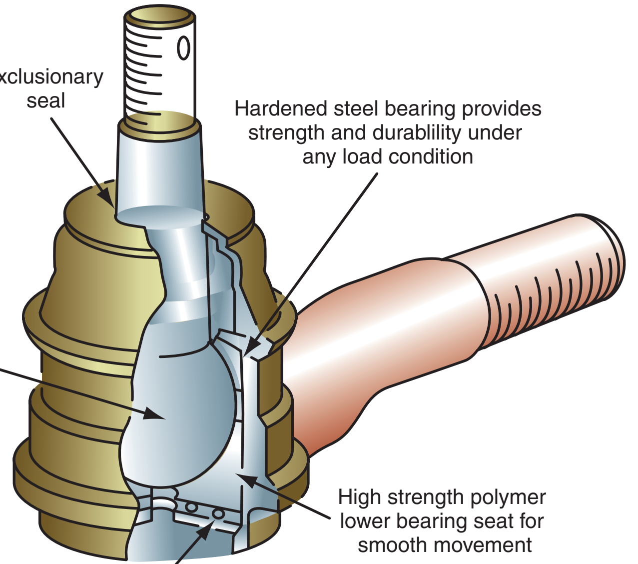


FIGURE 9-22 **Outer tie-rod end with hardened steel upper bearing and high-strength polymer lower bearing.**

Some outer tie-rod ends have a ball stud that is surrounded by an upper hardened steel bearing and a high-strength polymer lower bearing seat (Figure 9-22). The hardened steel upper bearing provides strength and durability, and the polymer lower bearing seat provides smooth rotation of the ball stud in the tie-rod end. An internal spring between the polymer lower bearing seat supplies self-adjusting action and constant tension on this seat. A seal in the upper part of the ball joint housing seals the ball stud to prevent contaminants from entering the tie-rod end. These tie-rod ends are installed on some original equipment manufacturer's vehicles, and they are available as replacement tie-rod ends on most vehicles.

Some Ford cars have rubber-encapsulated outer tie-rod ends in which a rubber bushing surrounds the lower end of the ball stud (Figure 9-23). Special service procedures required on

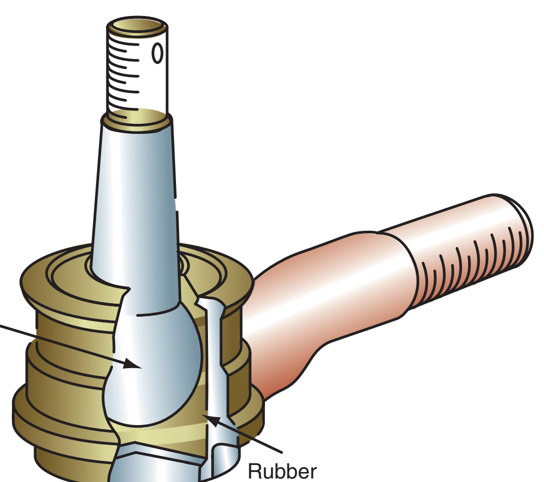


FIGURE 9-23 **Outer tie-rod end with rubber encapsulated ball stud.**

these tie-rod ends are explained in the Shop Manual. Similar outer tie-rod ends are used on parallelogram steering linkages and rack and pinion steering linkages.

Each tie-rod sleeve contains a left-hand and a right-hand thread where it is threaded onto the tie-rod end and the tie-rod. Therefore, sleeve rotation changes the tie-rod length and provides a toe adjustment. Clamps are used to tighten the tie-rod sleeves. The clamp opening must be positioned away from the slot in the tie-rod sleeve. The design of the steering linkage mechanism allows multiaxial movement, since the front suspension moves vertically and horizontally. Ball-and-socket-type pivots are used on the tie-rod assemblies and center link.

If the front wheels hit a bump, the wheels move up and down and the control arms move through their respective arcs. Since the tie-rods are connected to the steering arms, these rods must move upward with the wheel. Under this condition, the inner end of the tie-rod acts as a pivot, and the tie-rod also moves through an arc. This arc is almost the same as the lower control arm arc because the tie-rod is parallel to the lower control arm. Maintaining the same arc between the lower control arm and the tie-rod minimizes toe change on the front wheels during upward and downward wheel movement. This action improves the directional stability of the vehicle and reduces tread wear on the front tires.

Multiaxial movement refers to movement in any direction around a pivot point.

AUTHOR'S NOTE: It has been my experience that the most common causes of premature wear on outer tie-rod ends and other pivot points in a steering linkage are lack of lubrication or contamination that enters through broken seals. If the tie-rod ends and other pivot points have grease fittings, lubrication at the manufacturer's recommended interval is important to maintain component life. However, you should not overlubricate the steering linkage pivot points with a high-pressure grease gun, because this may rupture the seals. The steering linkage components are exposed to a large amount of water and dirt contamination. If the seals are leaking on any of the linkage pivot points, the pivots will soon be contaminated with moisture and dirt that acts as an abrasive to shorten component life.

Pitman Arm

The **pitman arm** connects the steering gear to the center link. This arm also supports the left side of the center link. Motion from the steering wheel and steering gear is transmitted to the pitman arm, and this arm transfers the movement to the steering linkage. This pitman arm movement forces the steering linkage to move to the right or left, and the linkage moves the front wheels in the desired direction. The pitman arm also positions the center link at the proper height to maintain the parallel relationship between the tie-rods and the lower control arms.

Wear-type pitman arms have ball sockets and studs at the outer end, and this stud fits into the center link opening (Figure 9-24). The ball stud and socket are subject to wear, and pitman arm replacement is necessary if the ball stud is loose in the pitman arm. A nonwear pitman arm has a tapered opening in the outer end. A ball stud in the center link fits into this opening. The nonwear pitman arm only needs replacing if the arm is damaged or bent in a collision. The opening in the inner end of both types of pitman arms has serrations that fit over matching serrations on the steering gear shaft. A nut and lock washer retain the pitman arm to the steering gear shaft.

Idler Arm

An idler arm support is bolted to the frame or chassis on the opposite end of the center link from the pitman arm. The **idler arm** is connected from the support bracket to the center link. Two bolts retain the idler arm bracket to the frame or chassis. In some idler arms, a ball stud on the outer end of the arm fits into a tapered opening in the center link (Figure 9-25), whereas in other idler arms, a ball stud in the center link fits into a tapered opening in the idler arm.

FIGURE 9-24 **Pitman arm design.**

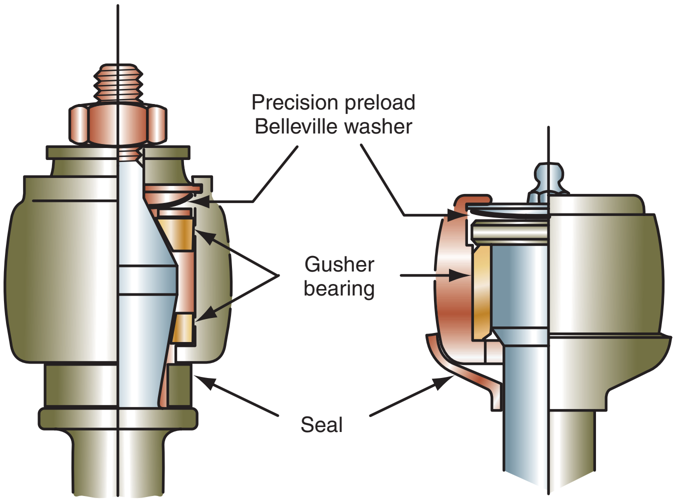
FIGURE 9-25 **Idler arm design.**

Steering wheel free play is the amount of steering wheel movement before the front wheels start to move to the right or left.

The idler arm supports the right side of the center link and helps maintain the parallel relationship between the tie-rods and the lower control arms. The outer end of the idler arm is designed to swivel on the idler arm bracket, and this swivel is subject to wear. A worn idler arm swivel causes excessive vertical steering linkage movement and erratic toe. This action results in excessive steering wheel free play with reduced steering control and front tire wear.

Some idler arms contain an upper and lower gusher bearing that surrounds the bearing surface on the lower end of the bracket. A newly designed idler arm has a one-piece powdered metal gusher bearing that extends the full length of the friction surface on the lower end of the bracket (Figure 9-26). Compared with previous designs, this new design has 50 percent more bearing surface, which provides extended service life. A Belleville washer installed below the gusher bearing maintains a precision preload on the thrust washer, bracket, and gusher bearing.

Other idler arms have a conical machined surface on the lower end of the bracket. This conical surface is seated on a matching conical surface on the bearing (Figure 9-27). A coil spring between the lower end of the bracket and the housing maintains constant upward pressure on the bracket to maintain minimal endplay and constant turning torque as the



ORIGINAL DESIGN **NEW DESIGN**

FIGURE 9-26 **Idler arm internal design.**

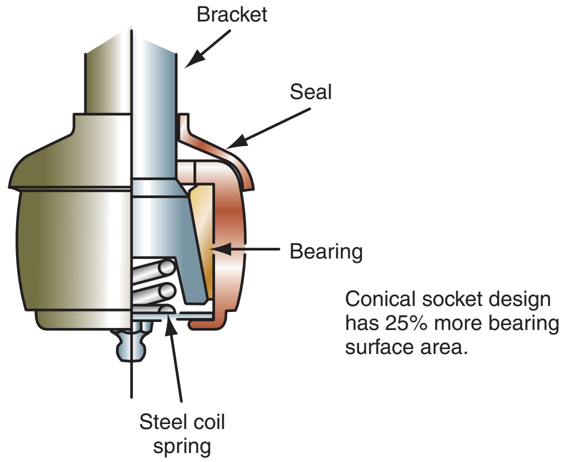


FIGURE 9-27 **Idler arm with conical bearing.**

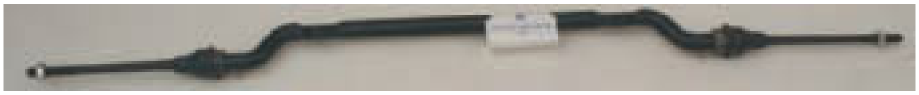


FIGURE 9-28 **Center link design.**

A **center link** may be referred to as a drag link, steering link, or intermediate link.

bearing wears. Since this type of idler arm maintains minimal endplay, more precise front suspension alignments are possible.

Center Links

The **center link** controls the sideways steering linkage and wheel movement. The center link together with the pitman arm and idler arm provides the proper height for the tie-rods, which is very important to minimizing toe change on road irregularities. Some center links have tapered openings in each end, and the studs on the pitman arm and idler arm fit into these openings. This type of center link may be called a taper end, or nonwear, link. Other wear-type center links have ball sockets in each end with tapered studs extending from the sockets (Figure 9-28). These tapered studs fit into openings in the pitman arm and idler arm, and they are retained with castellated nuts and cotter pins.

Rack and Pinion Steering Linkage

The **rack and pinion steering linkage** is used with rack and pinion steering gears. In this type of steering gear, the rack is a rod with teeth on one side. This rack slides horizontally on bushings inside the gear housing. The rack teeth are meshed with teeth on a pinion gear, and this pinion gear is connected to the steering column. When the steering wheel is turned, the pinion rotation moves the rack sideways. Tie-rods are connected directly from the ends of the rack to the steering arms. The tie-rods are similar to those found on parallelogram steering systems. An inner tie-rod end connects each tie-rod to the rack, and bellows boots are clamped to the gear housing. The bellows boots keep dirt out of these joints (Figure 9-29). The inner tie-rod end contains a spring-loaded ball socket. The outer tie-rod ends connected to the steering arms are basically the same as those in parallelogram steering linkages (Figure 9-30).

A Bit of History

For many years, rear-wheel-drive vehicles were equipped with parallelogram steering linkages. The smaller, lighter front-wheel-drive cars introduced in large numbers in the late 1970s and 1980s required a more compact, lighter steering gear. The rack and pinion steering gear is used almost exclusively on front-wheel-drive cars because of its reduced weight and space requirements.

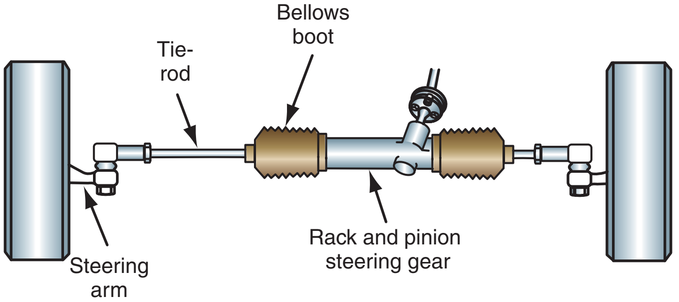


FIGURE 9-29 **Rack and pinion steering gear.**

FIGURE 9-30 **Inner tie-rod and outer tie-rod end, rack and pinion steering.**

Some inner tie-rod ends contain a bolt and bushing. These tie-rod ends are threaded onto the rack. Since the rack is connected directly to the tie-rods, the rack replaces the center link in a parallelogram steering linkage.

Some inner tie-rod ends have a mirror-finished ball and a high-strength polymer bearing to ensure low torque, minimal friction, and extended life (Figure 9-31). A hardened alloy steel rod extends from the ball to the outer tie-rod end and provides maximum strength and durability.

The rack and pinion steering gear may be mounted on the front crossmember (Figure 9-32) or attached to the cowl behind the engine (Figure 9-33). Rubber insulating bushings surround the steering gear, and these bushings are clamped to the crossmember or cowl. The rack and pinion steering gear is mounted at the proper height to position the tie-rods and lower control arms parallel to each other. The number of friction points is reduced in a rack and pinion steering system, and this system is light and compact. Most front-wheel-drive unibody vehicles have rack and pinion steering. Since the rack is linked directly to the steering arms, this type of steering linkage provides good road feel.

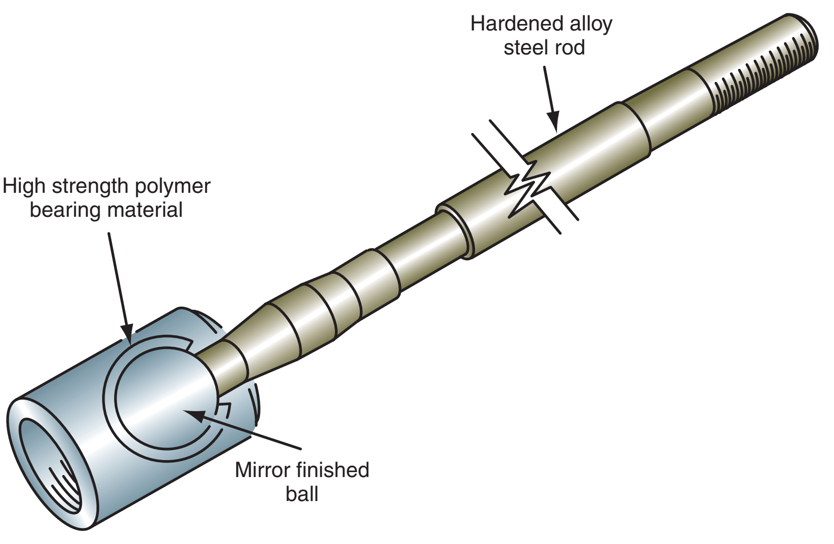


FIGURE 9-31 **Inner tie-rod design.**

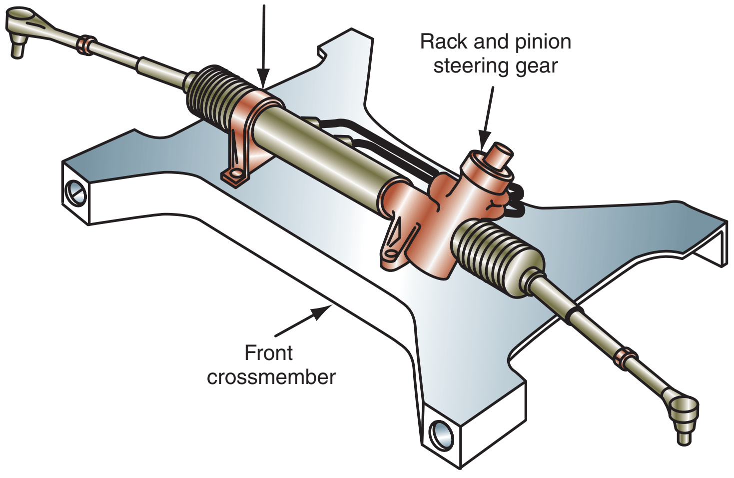


FIGURE 9-32 **Rack and pinion steering gear mounting on front crossmember.**

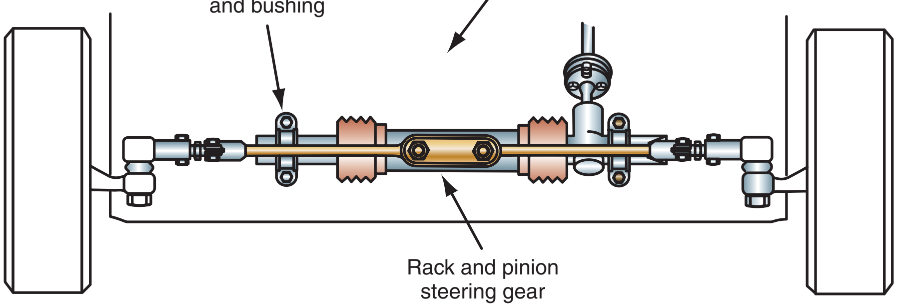


FIGURE 9-33 **Rack and pinion steering gear mounted on cowl.**

Steering Damper

A steering damper, or stabilizer, may be found on some parallelogram steering linkages and a few rack and pinion steering systems. The steering damper is similar to a shock absorber. This component is connected from one of the steering links to the chassis or frame (Figure 9-34).

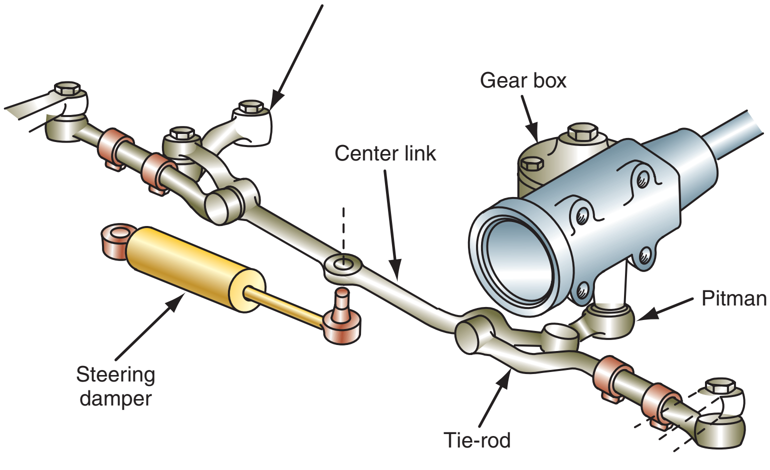


FIGURE 9-34 **Steering gear damper and linkage.**

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When a front wheel strikes a road irregularity, a shock is transferred from the front wheel to the steering linkage, steering gear, and steering wheel. The steering damper helps absorb this road shock and prevent it from reaching the steering wheel. Heavy-duty steering dampers are available for severe road conditions such as those sometimes encountered by four-wheel-drive vehicles.

Terms to Know

Air bag deployment module
Center link
Clock spring electrical connector
Energy-absorbing lower bracket
Idler arm
Parallelogram steering linkages
Pitman arm
Pre-safe system
Pyrotechnic
Rack and pinion steering linkage
Silencer
Spherical bearing
Spiral cable
Tie-rod
Toe plate

Summary

- Steering columns help provide steering control, driver convenience, and driver safety.
- Many steering columns provide some method of energy absorption to protect the driver during a frontal collision.
- Steering wheels and columns now contain an air bag deployment module to protect the driver in a frontal collision.
- Tilt steering columns increase driver comfort and ease while driving or getting in or out of the driver's seat.
- A clock spring electrical connector supplies positive electrical contact between the air bag module in the steering wheel and the air bag electrical system.
- The ignition switch, dimmer switch, signal light switch, hazard switch, and wipe/wash switch may be mounted in the steering column.
- When the ignition switch is in the Lock position, a locking plate and lever in the upper steering column locks the steering wheel and the gear shift.
- In some tilt steering columns, the upper column housing pivots on two bolts, and the upper steering shaft pivots on a universal joint.
- In a parallelogram steering linkage, the tie-rods are parallel to the lower control arms.
- The parallelogram steering linkage minimizes toe change as the control arms move up and down on road irregularities.
- A rack and pinion steering linkage has reduced friction points; it is lightweight and compact compared with a parallelogram steering linkage.

Review Questions

Short Answer Essays

1. Explain how a collapsible steering column protects the driver in a frontal collision.
2. Explain how the driver's side air bag protects the driver in a frontal collision.
3. Describe the purpose of a clock spring.
4. List the switches commonly found in a steering column.
5. Describe the type of mechanism used to lock the steering wheel and gear shift when the ignition is in the Lock position.
6. Describe the pivot points in the upper shaft and upper column tube in a tilt steering wheel.
7. List the wear points in a parallelogram steering linkage.
8. List the five main components in a parallelogram steering linkage, and explain the purpose of each component.
9. Describe the basic design of a rack and pinion steering linkage.
10. Explain the advantages of a rack and pinion steering linkage compared with a parallelogram steering linkage.

Fill-in-the-Blanks

1. In some collapsible steering columns, ____________ ______________ in the outer column jacket and steering shaft shear off if the driver is thrown against the steering wheel in a frontal collision.
2. The driver's side air bag protects the driver if the vehicle is involved in a ______________ collision above a specific speed.
3. In an air bag system, a _____________ _____________ in the steering column maintains positive electrical contact between the air bag module and the air bag electrical system as the steering wheel is rotated.
4. In a parallelogram steering linkage, the center link connects the pitman arm to the ________________ ________________ .
5. In a parallelogram steering linkage, the pitman arm and the ______________ ______________ position the center link and tie-rods at the correct height.
6. In a wear-type pitman arm, a ______________ ______________ is positioned in the outer end of the pitman arm.
7. In a parallelogram steering linkage, the tie-rods are parallel to the ______________ ______________ ______________ .
8. The clamp opening in a tie-rod sleeve must be positioned away from the ______________ in the tie-rod sleeve.
9. In a rack and pinion steering system, the rack is connected directly to the ______________ ______________.
10. Compared with a parallelogram steering linkage, a rack and pinion steering linkage has a reduced number of ______________ points.

Multiple Choice

1. A typical air bag deployment time is:
   A. 1.5 minutes.
   B. 1 minute.
   C. 30 seconds.
   D. 40 milliseconds.
2. Many collapsible steering columns have:
   A. Plastic pins in the two-piece outer jacket.
   B. A collapsible bellows in the two-piece outer jacket.
   C. Steel pins in the two-piece lower steering shaft.
   D. A rubber spacer in the two-piece lower steering shaft.
3. The clock spring electrical connector:
   A. Maintains electrical contact between the air bag inflator module and the air bag electrical system.
   B. Is mounted above the steering wheel.
   C. Contains three spring-loaded copper contacts.
   D. Provides electrical contact between the signal light switch and the signal lights.
4. An active steering column has all of these components EXCEPT:
   A. A pyrotechnic actuator.
   B. A section of energy-absorbing steel.
   C. A telescoping cylinder.
   D. A pull-out pin that allows easier column collapse.
5. All of these statements about rack and pinion steering linkages are true EXCEPT:
   A. The tie-rods are parallel to the lower control arms.
   B. The tie-rod position depends on the steering gear mounting.
   C. The tie-rods are connected to the pinion in the steering gear.
   D. The outer tie-rod ends connect the tie-rods to the steering arms.
6. All these statements about parallelogram steering linkages are true EXCEPT:
   A. Tie-rod sleeves have the same type of thread in both ends of the sleeve.
   B. Loose steering linkages may cause excessive tire tread wear.
   C. Loose steering linkage causes excessive steering wheel free play.
   D. The pitman arm helps maintain the proper center link and tie-rod height.
7. While discussing idler arms:
   A. Some idler arms contain a tapered roller bearing.
   B. The idler arm bracket is bolted to the upper control arm.
   C. A worn idler arm has no effect on front wheel toe.
   D. A partially seized idler arm bearing increases steering effort.

8. In a parallelogram steering linkage, the tie-rods are parallel to the lower control arms to:
   A. Improve ride quality.
   B. Provide longer steering linkage life.
   C. Extend shock absorber and spring life.
   D. Reduce toe change during upward and downward front wheel movement.
9. A rack and pinion steering gear:
   A. Has tie-rods that connect the rack directly to the steering arms.
   B. May be bolted to the vehicle frame.
   C. Has inner tie-rod ends that are pressed onto the rack.
   D. Has more friction points compared with a parallelogram steering linkage.
10. While discussing steering linkages and dampers:
   A. In a rack and pinion steering gear, the rack positions the tie-rods parallel to the lower control arms.
   B. A rack and pinion steering gear is used on most rear-wheel-drive cars.
   C. A steering damper is used on many front-wheel-drive vehicles.
   D. A defective steering damper may cause excessive steering effort.

Chapter 9

Steering Column and Linkage Diagnosis and Service

Upon completion and review of this chapter, you should be able to:

- Diagnose steering columns.
- Remove and replace steering wheels on air-bag-equipped vehicles and non-air-bag-equipped vehicles.
- Remove and replace air bag deployment modules and clock spring electrical connectors.
- Remove and replace steering columns.
- Inspect collapsible steering columns for damage.
- Disassemble steering columns.
- Inspect steering column components and replace necessary parts.
- Assemble steering columns.
- Diagnose and service flexible couplings and universal joints.
- Diagnose steering linkage mechanisms.
- Diagnose, remove, and replace tie-rod ends.
- Diagnose, remove, and replace pitman arms.
- Diagnose, remove, and replace center links.
- Diagnose, remove, and replace idler arms.
- Diagnose, remove, and replace steering dampers.
- Diagnose steering arms.

When servicing or replacing steering wheels, columns, and linkages, technicians actually have the customer's life in their hands. If steering components are not serviced properly and not tightened to the specified torque, the steering may become disconnected, resulting in a complete loss of steering control. This condition may cause a collision, resulting in vehicle damage, personal injury, and an expensive lawsuit for the technician and the shop where he or she is employed. Therefore, when performing any automotive service, always be sure the vehicle manufacturer's recommended service procedures and torque specifications are followed.

BASIC TOOLS

Basic technician's tool set

Service manual

Steering wheel puller

Foot-pound torque wrench

Machinist's rule

1/4″ Electric drill

Set of drill bits

Screw extractors

Air Bag Deployment Module, Steering Wheel, and Clock Spring Electrical Connector Removal and Replacement

Prior to working on an air bag system, always disconnect the negative battery cable and wait one minute before proceeding with the diagnostic or service work. Many air bag systems have a **backup power supply** circuit designed into the air bag computer or located in a separate

Customer Care: Before disconnecting the negative battery cable, note how the customer has the radio stations programmed, and reset the radio and clock after the negative battery cable is reconnected.

CAUTION:
Always disconnect the negative battery terminal and wait one minute before diagnosing or servicing any air bag system component. Failure to observe this precaution may result in accidental air bag deployment. Air bag service precautions vary depending on the vehicle. Always follow the vehicle manufacturer's air bag service precautions in the service manual.

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An air bag deployment module may be referred to as a steering wheel pad.

module. This backup power supply provides power to deploy the air bag for a specific length of time after the battery power is disconnected in a collision. One minute after the negative battery terminal is disconnected, this backup power supply is powered down, and no power is available to deploy the air bag while the battery remains disconnected.

An air bag warning light in the instrument panel indicates the status of the air bag system. On some vehicles, this warning light should be illuminated for a few seconds when the ignition switch is turned on. The warning light should remain off while cranking the engine, and it should be on for a few seconds after the engine starts. After the engine has been running for a few seconds, the air bag warning light should remain off. On other vehicles, the air bag warning light flashes 7 to 9 times when the ignition switch is turned on and after the engine is started. The air bag warning light operation varies depending on the make and model year of the vehicle. Always check the vehicle manufacturer's service manual for the exact air bag warning light operation. When the air bag warning light does not operate as specified by the vehicle manufacturer, the air bag system is defective, and the air bag or bags will probably not deploy if the vehicle is involved in a collision.

Air bag module and steering wheel removal and replacement procedures vary depending on the vehicle. Always follow the vehicle manufacturer's recommended procedure in the service manual.

The following is a typical air bag module and steering wheel removal and replacement procedure:

1. Turn the ignition switch to the Lock position and place the front wheels facing straight ahead.
2. Remove the negative battery terminal and wait for the specified time period.
3. Loosen the three air-bag-retaining Torx screws under the steering wheel (Figure 9-1).
4. Loosen the other two air-bag-retaining Torx screws under the steering wheel (Figure 9-2). Loosen all five Torx screws until the groove along the screw circumference catches on the screw case. Some air bag deployment modules are retained on top of the steering wheel with a spring-loaded clip. To release this clip, insert a flat-tipped screw driver into the slot at the lower edge of the steering wheel and turn the screw driver 1/4 turn to release the clip.

WARNING: When an air bag deployment module is temporarily stored on the workbench, always place this module face upward. If the air bag deployment module accidentally deployed when facing downward, the module would become a projectile, and personal injury might result.

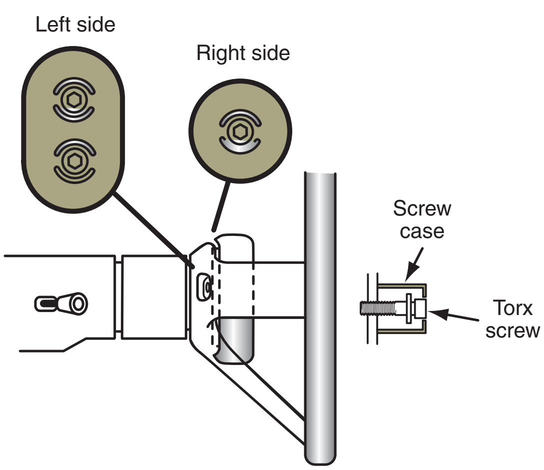

FIGURE 9-1 **Three air-bag–retaining Torx screws.**

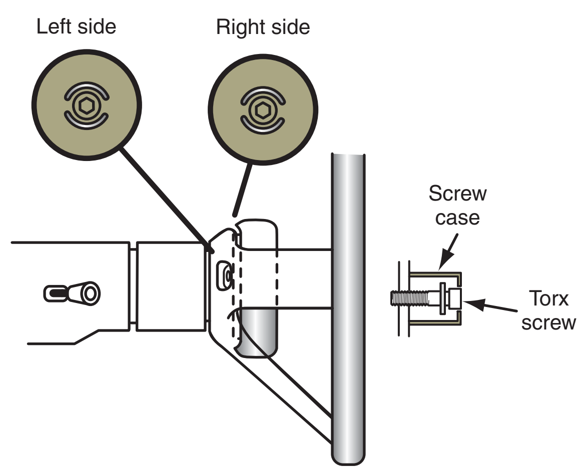

FIGURE 9-2 **Two air-bag–retaining Torx screws.**

FIGURE 9-3 Disconnecting the air bag module electrical connector.

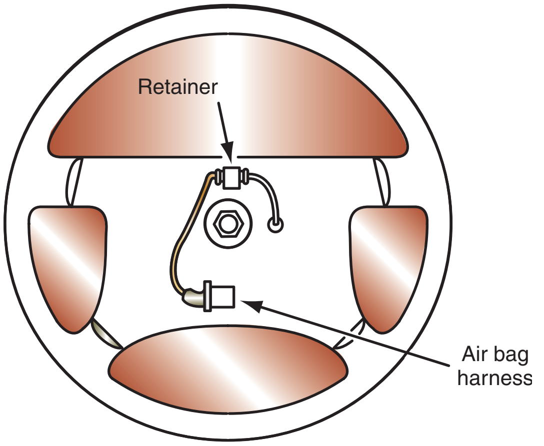

FIGURE 9-4 Disconnecting the air bag wiring retainer.

5. Pull the **air bag deployment module** from the steering wheel and disconnect the air bag module electrical connector (Figure 9-3). Do not pull on the air bag wires in the steering column. Place the air bag deployment module face upward on the workbench.
6. Disconnect the air bag wiring retainer in the steering wheel (Figure 9-4).
7. Use the proper size socket and a ratchet to remove the steering wheel retaining nut.
8. Observe the matching alignment marks on the steering wheel and the steering shaft. If these alignment marks are not present, place alignment marks on the steering wheel and steering shaft with a center punch and a hammer.

The **air bag deployment module** contains the air bag, inflation chemicals, and an igniting device.

WARNING: Photo Sequence 15 shows a typical procedure for removing a steering wheel. Do not pull on the steering wheel in an attempt to remove it from the steering shaft. The steering wheel may suddenly come off, resulting in personal injury, or the steering wheel may be damaged by the pulling force.

CAUTION:
On an air-bag-equipped vehicle, the wait time prior to servicing electrical components after the negative battery terminal is disconnected varies depending on the vehicle make and model year. Always follow the wait time and all other service precautions recommended in the vehicle manufacturer's service manual.

9. Install a steering wheel puller with the puller bolts threaded into the bolt holes in the steering wheel. On some vehicles, the steering wheel has slots for the pulley adapters to fit into rather than threaded bolt holes. This design prevents the possibility of the technician turning the bolts too far into the steering wheel and damaging components below the steering wheel. Tighten the puller nut to remove the steering wheel (Figure 9-5). Visually check the steering wheel condition. If the steering wheel is bent or cracked, replace the wheel.

FIGURE 9-5 Removing steering wheel with the proper steering wheel puller.

PHOTO SEQUENCE 15

Typical Procedure for Removing a Steering Wheel

P15-1 **Check and record the radio stations programmed in the stereo system.**

P15-2 **Look up the car manufacturer's steering wheel removal procedure in the service manual.**

P15-3 **Disconnect the negative battery cable, and wait for the car manufacturer's specified length of time.**

P15-4 **Remove the air bag deployment module retaining screws under the steering wheel.**

P15-5 **Lift the air bag deployment module upward from the steering wheel, and disconnect the module wiring connector.**

P15-6 **Set the air bag deployment module face upward on the workbench.**

P15-7 **Loosen and remove the steering wheel retaining nut.**

P15-8 **Observe the alignment marks on the steering wheel and shaft.**

P15-9 **Connect the proper steering wheel puller to the steering wheel.**

P15-10 **Turn the puller screw to loosen the steering wheel on the shaft.**

P15-11 **Remove the puller from the steering wheel.**

P15-12 **Lift the steering wheel off the shaft.**

10. Disconnect the four retaining screws and remove the **clock spring electrical connector** (Figure 9-6).
11. Be sure the front wheels are facing straight ahead. Turn the clock spring electrical connector counterclockwise by hand until it becomes harder to turn as it becomes fully wound in that direction.
12. Turn the clock spring electrical connector clockwise three turns and align the red mark on the center part of the spring face with the notch in the cable circumference (Figure 9-7). This action centers the clock spring electrical connector.
13. Install the clock spring electrical connector and tighten the four retaining screws to the specified torque.
14. Align the marks on the steering wheel and the steering shaft, and install the steering wheel on the shaft.
15. Install the steering wheel retaining nut and tighten this nut to the specified torque.
16. Install the air bag wiring retainer in the steering wheel.
17. Hold the air bag deployment module near the top of the steering wheel and connect the air bag module connector.
18. Install the air bag deployment module in the top of the steering wheel and tighten the five retaining Torx screws.
19. Reconnect the negative battery cable.
20. Reset the clock and radio.

CAUTION:
Always use the vehicle manufacturer's recommended tools when diagnosing or servicing an air bag system or the electrical system on an air-bag-equipped vehicle. Do not use a 12-V test light or a self-powered test light to diagnose air bag systems or electrical systems on air-bag-equipped vehicles. **Accidental air bag deployment** may result from improper use of tools.

A **clock spring electrical connector** may be called a coil, spiral cable, or cable reel. The clock spring electrical connector connects the air bag electrical system to the air bag deployment module and allows steering wheel rotation.

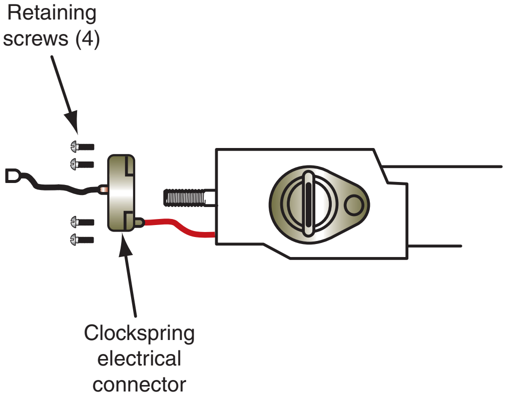

FIGURE 9-6 **Removing clock spring electrical connecter.**

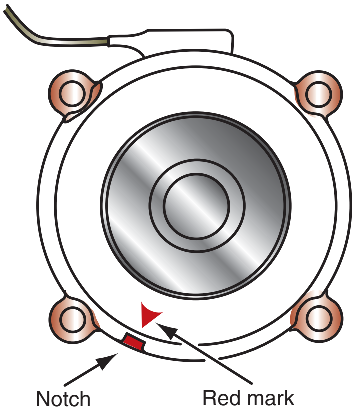

FIGURE 9-7 **Centering clock spring electrical connecter.**

SERVICE TIP: When servicing air bag components on some recent model vehicles, the vehicle manufacturer recommends disconnecting the air bag components only in the zone or area on the vehicle where service work is required rather than disconnecting the negative battery cable.

If the vehicle is not equipped with an air bag, the steering wheel removal and replacement procedure is basically the same, but all steps pertaining to the air bag module and clock spring are not required. On a non-air-bag–equipped vehicle, the center steering wheel cover must be removed to access the steering wheel retaining nut.

CUSTOMER CARE: While servicing a vehicle, always inspect the operation of the indicator lights or gauges in the instrument panel. These lights or gauges may indicate a problem that the customer has been ignoring. For example, if the air bag warning light is not operating properly, the air bag or bags may not deploy in a collision, resulting in serious injury to the driver and/or passenger. If the air bag warning light is not working properly, always advise the customer that he or she will not be protected by the air bag in a collision, and the vehicle should not be driven under this condition.

Steering Column Service

Some steering column service can be performed with the column installed in the vehicle. In some steering columns removal and replacement of the various switches in the column is possible with the column installed in the vehicle. Always follow the recommended service procedure in the vehicle manufacturer's service manual.

Steering Column Removal and Replacement

Steering column removal and replacement procedures vary depending on the vehicle make, type of steering column, and gearshift lever position. Always follow the vehicle manufacturer's recommended procedure in the service manual.

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The following is a typical steering column removal and replacement procedure:

1. Disconnect the negative battery cable. If the vehicle is equipped with an air bag, wait one minute.
2. Install a seat cover on the front seat.
3. Place the front wheels in the straight-ahead position and remove the ignition key from the switch to lock the steering column.
4. Remove the cover under the steering column and remove the lower finish panel if necessary.
5. Disconnect all wiring connectors from the steering column.
6. If the vehicle has a column-mounted gearshift lever, disconnect the gearshift linkage at the lower end of the steering column. If the vehicle has a floor-mount gearshift, disconnect the shift interlock.
7. Remove the retaining bolt or bolts in the lower universal joint or flexible coupling.
8. Remove the steering-column-to-instrument-panel mounting bolts.
9. Carefully remove the steering column from the vehicle. Be careful not to damage the upholstery or paint.
10. Install the steering column under the instrument panel and insert the steering shaft into the lower universal joint.
11. Install the steering-column-to-instrument-panel mounting bolts. Be sure the steering column is properly positioned, and tighten these bolts to the specified torque.
12. Install the retaining bolt or bolts in the lower universal joint or flexible coupling, and tighten the bolts to the specified torque.
13. Connect the gearshift linkage if the vehicle has a column-mounted gearshift.
14. Connect all the wiring harness connectors to the steering column connectors.

CAUTION: Do not hammer on the top of the steering shaft to remove the steering wheel. This action may damage the shaft.

15. Install the steering column cover and the lower finish panel.
16. Reconnect the negative battery cable.
17. Road test the vehicle and check for proper steering column operation.

Collapsible Steering Column Inspection

Since steering column design varies depending on the vehicle, the **collapsible steering column** inspection procedure should be followed in the vehicle manufacturer's service manual.

The following is a typical collapsible steering column inspection procedure:

1. Measure the clearance between the capsules and the slots in the steering column bracket (Figure 9-8). If this measurement is not within specifications, replace the bracket.
2. Inspect the contact between the bolt head and the bracket (Figure 9-9). If the bolt head contacts the bracket, the shear load is too high, and the bracket must be replaced.
3. Inspect the steering column jacket for **sheared injected plastic** in the openings on the side of the jacket (Figure 9-10). If sheared plastic is present, the column is collapsed. Measure the distance from the end of the bearing assembly to the lower edge of the upper steering column jacket (Figure 9-11). If this distance is not within the vehicle manufacturer's specification, a new jacket must be installed.
4. Visually inspect the gearshift tube for sheared injected plastic. If the gearshift tube indicates sheared plastic, replace the tube.
5. Remove the intermediate steering shaft between the column and the steering gear. Position a dial indicator stem against the lower end of the steering shaft, and rotate the steering wheel. If the runout on the dial indicator exceeds the vehicle manufacturer's specification, the steering shaft is bent and must be replaced.
6. If the steering shaft is not bent but shows sheared injected plastic (Figure 9-12), this shaft may be repaired with a service repair package.

CAUTION: If the steering wheel puller bolts are too long, they will extend through the steering wheel and damage the clock spring.

CAUTION: Failure to center a clock spring prior to installation may cause a broken conductive tape in the clock spring.

A **collapsible steering column** allows the column to move away from the driver if the driver impacts the column during a collision.

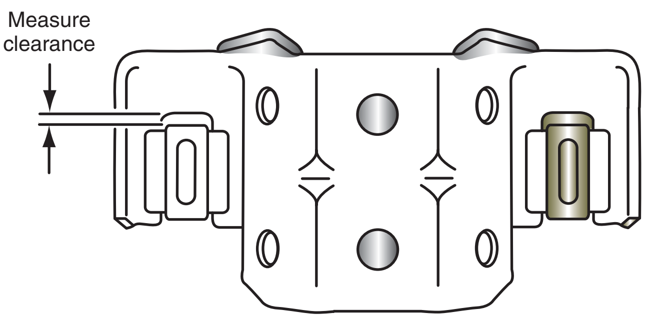

FIGURE 9-8 **Capsules in steering column bracket.**

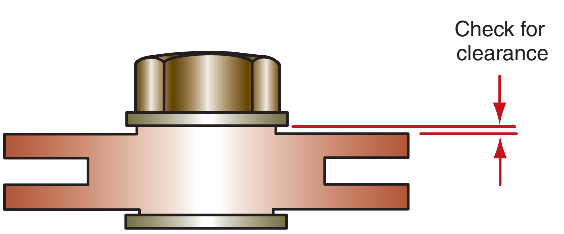

FIGURE 9-9 **Bolt head to bracket clearance.**

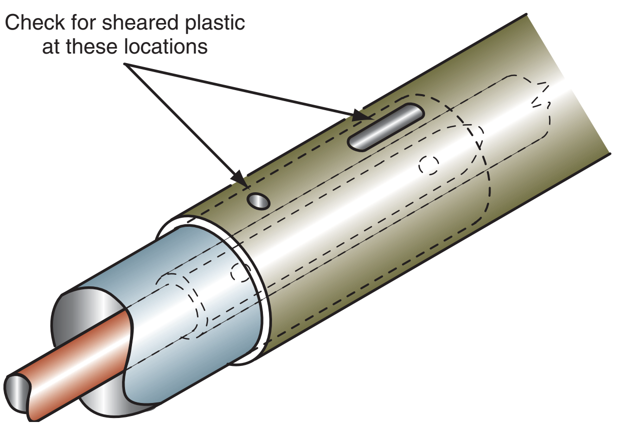

FIGURE 9-10 **Inspecting for sheared plastic in jacket openings.**

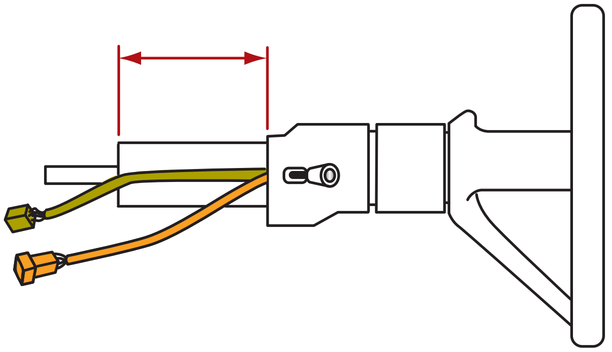

FIGURE 9-11 **Measuring distance from the end of the bearing assembly to the upper steering column jacket.**

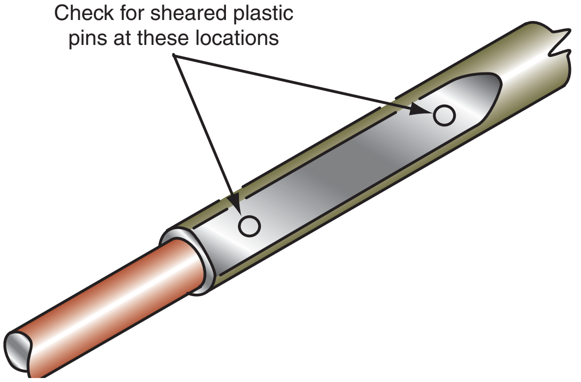

FIGURE 9-12 **Inspecting for sheared injected plastic in steering shaft.**

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Tapered-head bolts have a tapered head with no provision for connecting any type of wrench to the bolt.

Tilt Steering Column Disassembly

Since there are many variations in steering column design, always follow the vehicle manufacturer's recommended steering column disassembly procedure in the service manual.

The following is a typical tilt steering column disassembly procedure:

1. Remove the air bag deployment module, steering wheel, and spiral cable, as mentioned previously in this chapter.
2. Remove the ignition key cylinder illumination mounted on top of the ignition switch cylinder (Figure 9-13).
3. Remove the universal joint from the lower end of the steering shaft.
4. Remove the steering column protector and the wiring harness clamp mounted under the steering column.
5. Remove the steering damper mounted near the top of the column.
6. Remove the retaining screw and the combination switch with the wiring harness (Figure 9-14).
7. Mark the center of the **tapered-head bolts** on the steering column with a center punch. Use a 0.120 to 0.160 in. (3 to 4 mm) drill bit to drill into the tapered-head bolts (Figure 9-15).
8. Remove the tapered-head bolts with a screw extractor, and separate the upper bracket and column tube (Figure 9-16).

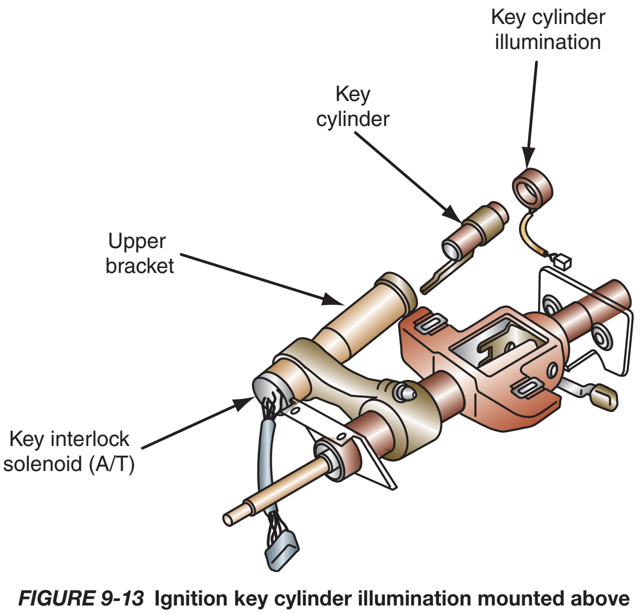

FIGURE 9-13 **Ignition key cylinder illumination mounted above ignition switch cylinder.**

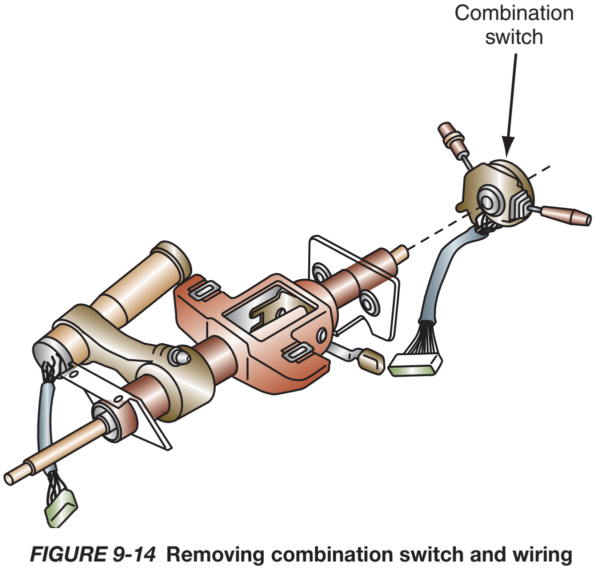

FIGURE 9-14 **Removing combination switch and wiring harness.**

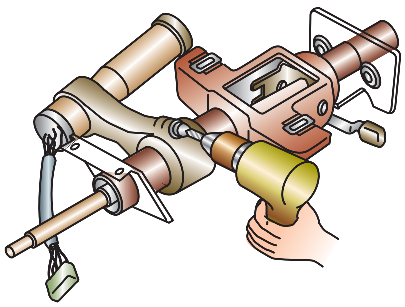

FIGURE 9-15 **Drilling tapered-head bolts.**

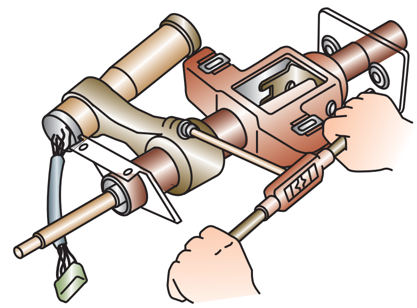

FIGURE 9-16 **Removing tapered-head bolts with a screw extractor.**

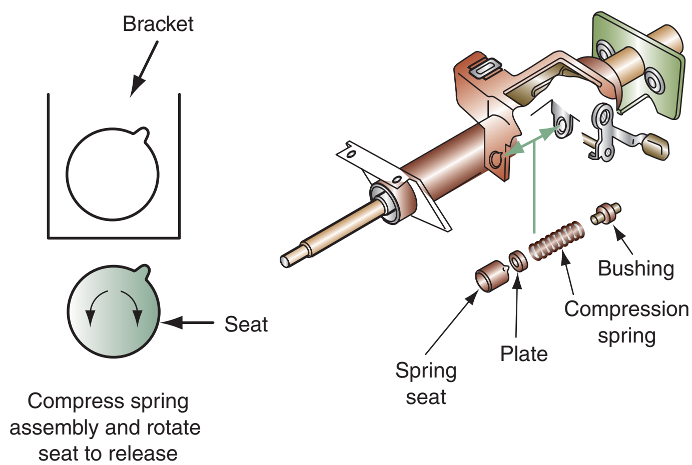

FIGURE 9-17 **Removing compression spring, seat, and bushing.**

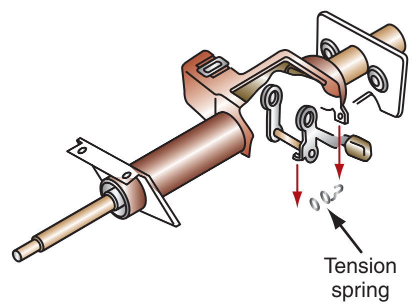

FIGURE 9-18 **Removing tension spring.**

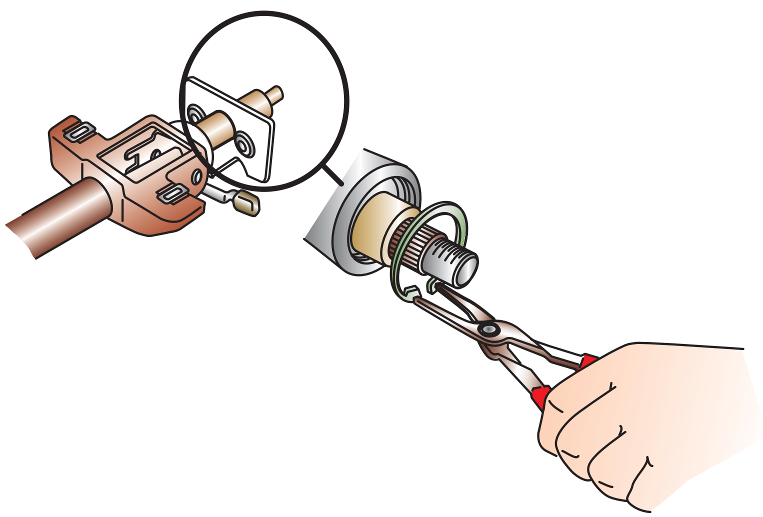

FIGURE 9-19 **Removing snapring from upper column tube.**

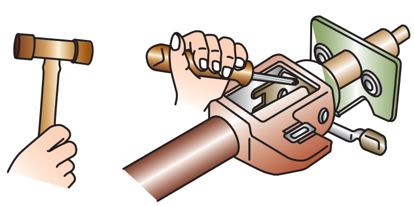

FIGURE 9-20 **Loosening staked parts in upper column tube.**

9. Grasp the compression spring seat with a pair of pliers and turn the seat to release the seat, compression spring, and bushing (Figure 9-17).
10. Grasp the tension spring with a pair of pliers and extend this spring to remove it from the column (Figure 9-18).
11. Remove the snapring from the upper column tube with snapring pliers (Figure 9-19).
12. Use a soft hammer and a screwdriver to loosen the staked parts of the upper column tube (Figure 9-20).

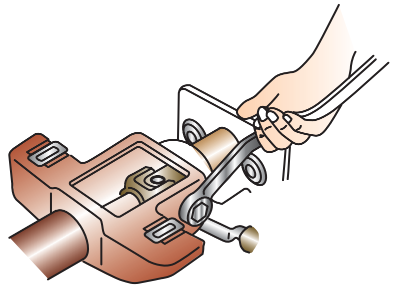

FIGURE 9-21 **Removing nuts on upper column pivot bolts.**

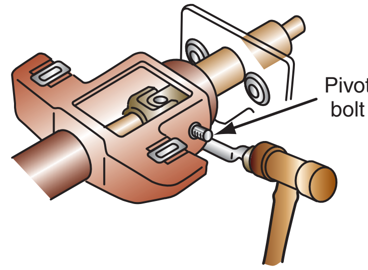

FIGURE 9-22 **Removing pivot bolts from steering column.**

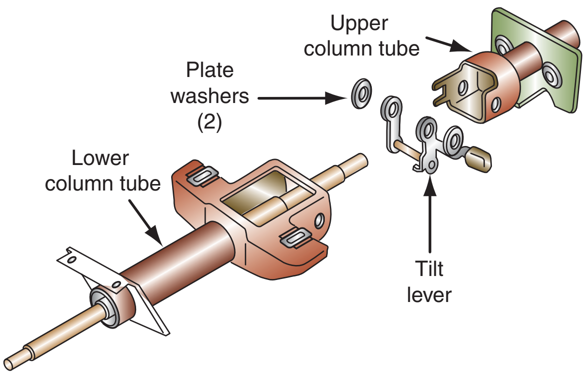

FIGURE 9-23 **Removing upper column tube, tilt lever assembly, and plate washers.**

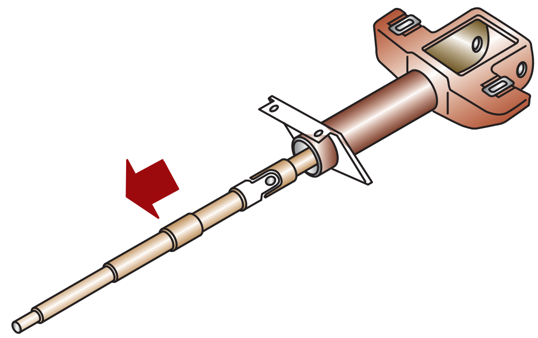

FIGURE 9-24 **Removing steering shaft from the steering column.**

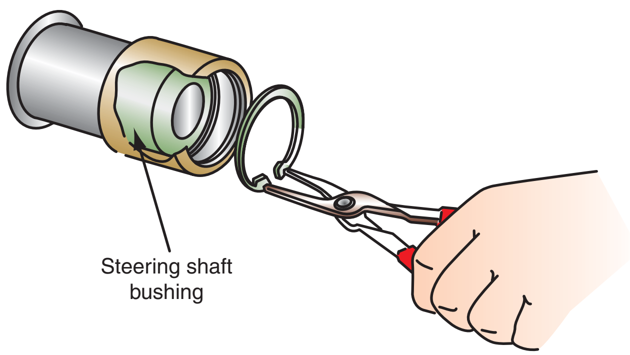

FIGURE 9-25 **Removing snapring above steering shaft bushing.**

13. Remove the two nuts on the upper column pivot bolts (Figure 9-21).
14. Use a plastic hammer to tap the pivot bolts out of the column (Figure 9-22).
15. Remove the upper column tube, tilt lever assembly, and plate washers (Figure 9-23).
16. Remove the steering shaft from the column (Figure 9-24).
17. Use snapring pliers to remove the snapring above the steering shaft bushing (Figure 9-25). Remove the steering shaft bushing.

Tilt Steering Column Inspection and Parts Replacement

1. Place the ignition key in the switch and move the key through all the switch positions. Be sure the operating pin moves properly in the switch mechanism (Figure 9-26). If the ignition key cylinder must be replaced, turn the key to the accessory (ACC) position. Use a small steel rod to push down on the stop pin near the bottom of the key cylinder

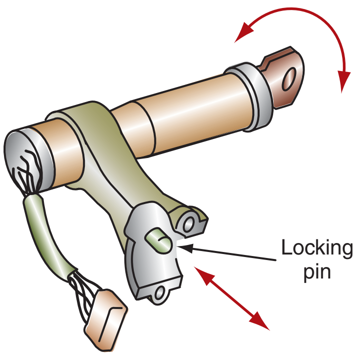

FIGURE 9-26 **Inspecting ignition switch operation.**

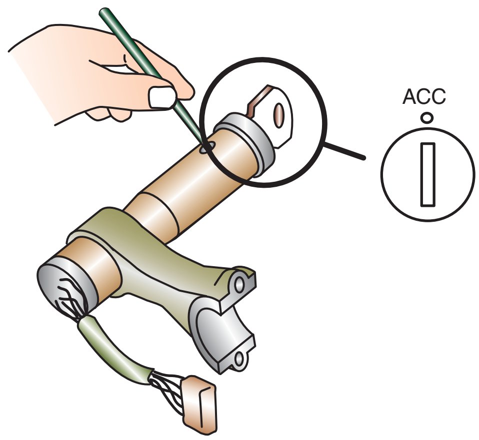

FIGURE 9-27 **Depressing stop pin in release ignition switch cylinder.**

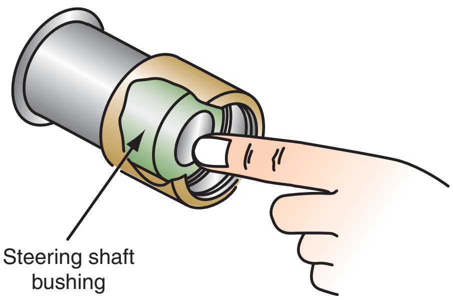

FIGURE 9-28 **Inspecting upper steering shaft bearing.**

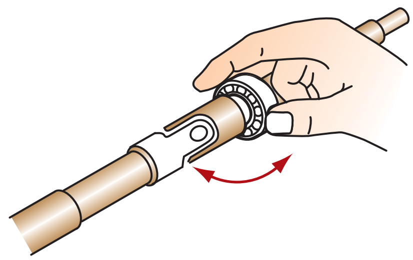

FIGURE 9-29 **Inspecting lower steering shaft bearing.**

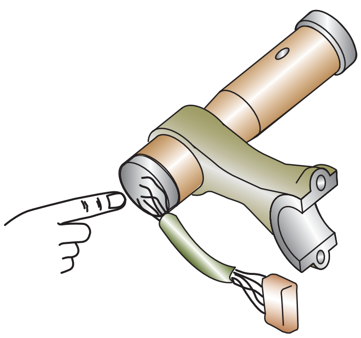

FIGURE 9-30 **Inspecting ignition key interlock solenoid.**

(Figure 9-27) and pull the cylinder out of the housing. Install the new key cylinder with the key in the ACC position.

2. Rotate the upper steering shaft bearing and inspect for noise, looseness, and wear (Figure 9-28). If any of these conditions are present, replace the upper tube.
3. Inspect the lower steering shaft bearing for noise, looseness, and wear (Figure 9-29). Replace this bearing if necessary.
4. Inspect the ignition key interlock solenoid for damaged wires and loose mounting screws (Figure 9-30). Repair or replace this solenoid as required.

Molybdenum disulphide lithium-based grease is a special grease that is applied to contacting parts in a tilt steering column.

Tilt Steering Column Assembly

1. Coat all rubbing parts with **molybdenum disulphide lithium-based grease.** Install the steering shaft bushing and the bushing snapring (Figure 9-31).

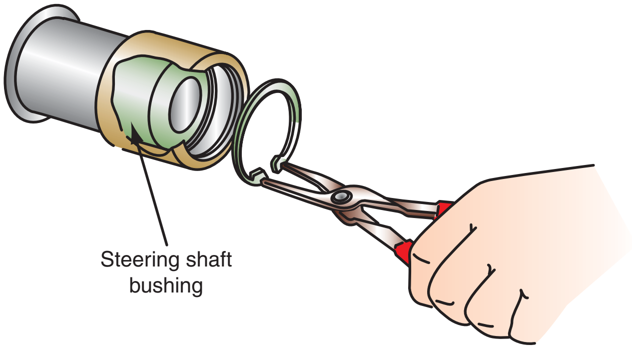

FIGURE 9-31 **Installing steering shaft bushing and snapring.**

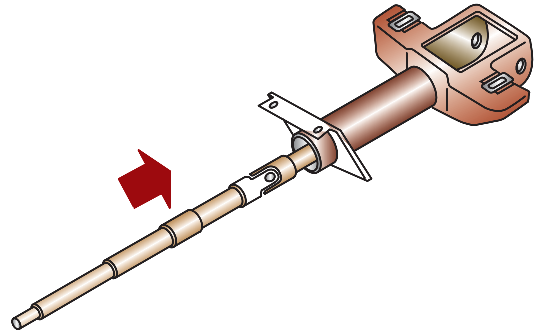

FIGURE 9-32 **Installing the steering shaft in the lower tube.**

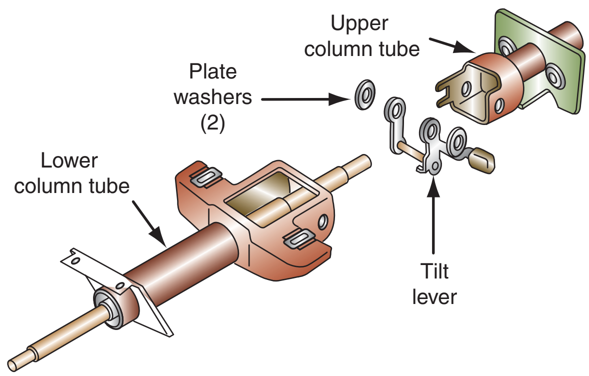

FIGURE 9-33 **Installing upper column tube, tilt lever mechanism, and two plate washers.**

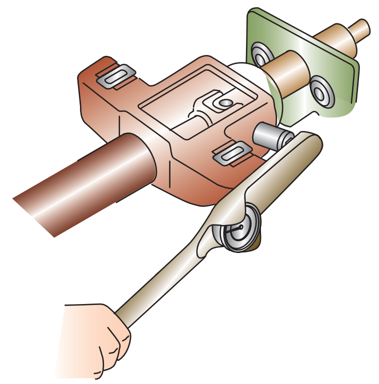

FIGURE 9-34 **Tightening pivot bolt nuts.**

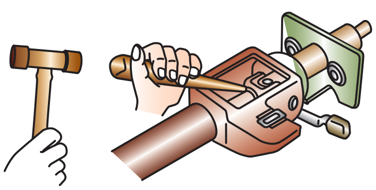

FIGURE 9-35 **Tapping steering shaft into upper column tube.**

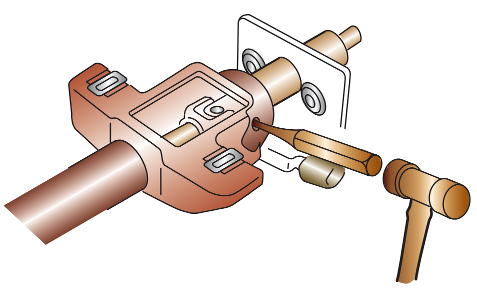

FIGURE 9-36 **Staking upper column tube.**

2. Install the steering shaft in the lower tube (Figure 9-32).
3. Install the upper column tube, tilt lever mechanism, and two plate washers (Figure 9-33). Install the two pivot bolts.
4. Install the pivot bolt nuts and tighten these nuts to the specified torque (Figure 9-34).
5. Use a brass bar and a hammer to tap the steering shaft into the upper column tube (Figure 9-35).
6. Stake the upper column tube with a pin punch and a hammer (Figure 9-36).
7. Install the snapring in the top of the upper column tube (Figure 9-37).
8. Install the tension spring (Figure 9-38). Assemble the compression spring, bushing, plate, and seat. Use a vise to install the compression spring and related components (Figure 9-39).
9. Install the upper bracket with two new tapered-head bolts. Tighten the tapered-head bolts until the tapered head breaks off (Figure 9-40).

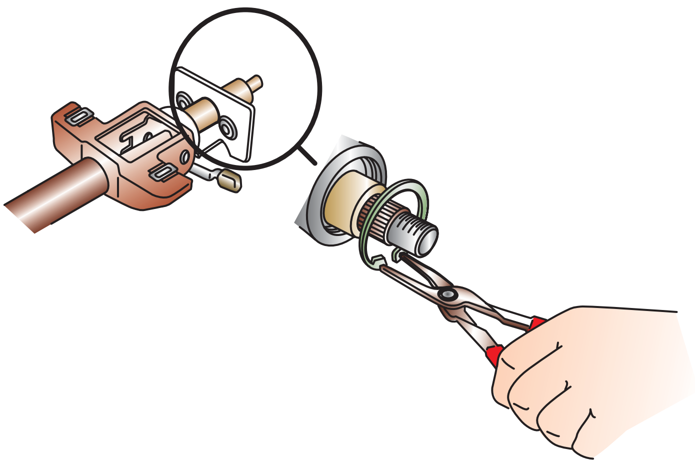

FIGURE 9-37 **Installing snapring in upper column tube.**

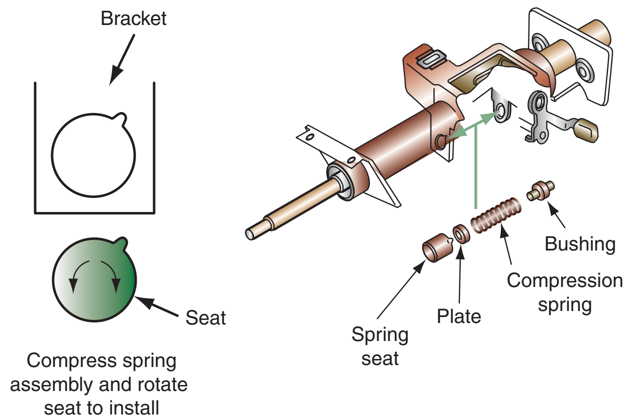

FIGURE 9-38 **Installing tension spring.**

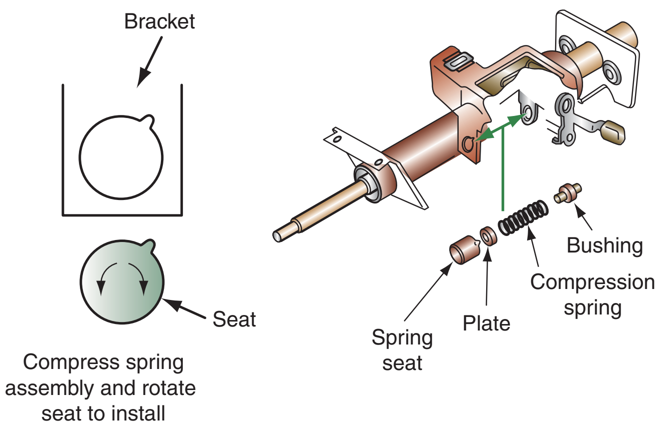

FIGURE 9-39 **Installing compression spring.**

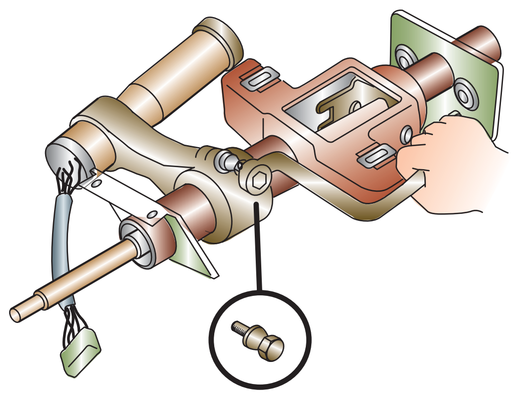

FIGURE 9-40 **Tightening tapered-head bolts in upper bracket.**

10. Install the protector and wiring harness clamp.
11. Install the steering damper and ignition key illumination.
12. Install the universal joint on the bottom of the steering shaft and tighten the retaining bolt to the specified torque.
13. Install the combination switch and wiring harness and tighten the retaining screw to the specified torque.
14. Install the spiral cable, steering wheel, and air bag deployment module as mentioned earlier in this chapter.

Steering Column Flexible Coupling and Universal Joint Diagnosis and Service

Checking Steering Wheel Free Play

With the engine stopped and the front wheels in the straight-ahead position, move the steering wheel in each direction with light finger pressure. Measure the amount of steering wheel movement before the front wheels begin to turn (Figure 9-41). This movement is referred to as **steering wheel free play.** On some vehicles, this measurement should not exceed 1.18 in. (30 mm). Always refer to the vehicle manufacturer's specifications. Excessive steering wheel free play is caused by worn steering shaft universal joints or flexible coupling. Other causes of excessive steering wheel free play include worn steering linkage mechanisms and a worn or out of adjustment steering gear.

Steering wheel free play is the amount of steering wheel movement before the front wheels start to turn.

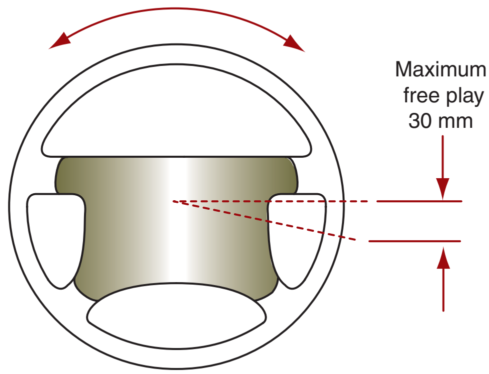

FIGURE 9-41 **Measuring steering wheel free play.**

A worn universal joint or flexible coupling in the steering column may also cause rattling noises. The rattling noises may occur while driving the vehicle straight ahead on irregular road surfaces. With the normal vehicle weight resting on the front suspension, observe the flexible coupling or universal joint as an assistant turns the steering wheel 1/2 turn in each direction. If the vehicle has power steering, the engine should be running with the gear selector in Park. The flexible coupling or universal joint must be replaced if there is free play in this component.

Flexible Coupling Replacement

If the flexible coupling must be replaced, loosen the coupling-to-steering-gear-stub-shaft bolt. Disconnect the steering column from the instrument panel, and move the column rearward until the flexible coupling can be removed from the steering column shaft. Remove the coupling-to-steering-shaft bolts, and disconnect the coupling from the shaft. When the new coupling and the steering column are installed on some vehicles, the clearance between the coupling clamp and the steering gear adjusting plug should be 1/16 in. (1.5 mm) (Figure 9-42). This specification may vary depending on the vehicle. Always use the vehicle manufacturer's specifications in the service manual.

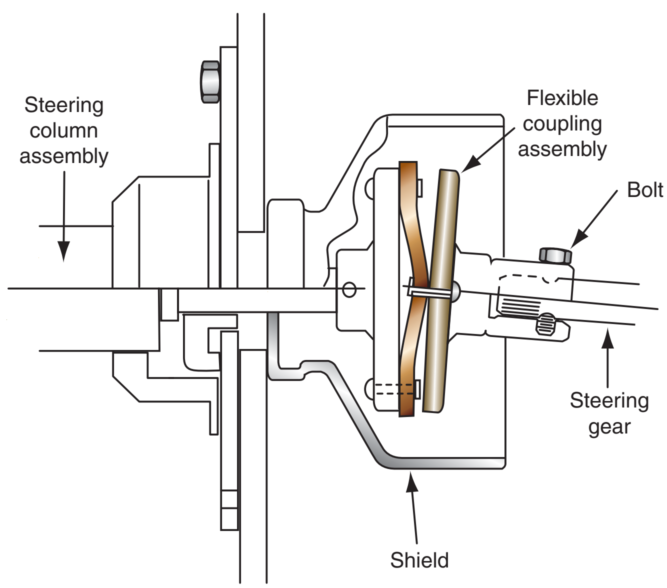

FIGURE 9-42 **Flexible coupling installation.**

Steering Column Diagnosis

There are variations in steering columns depending on the vehicle, type of transmission, and the transmission gear selector position. Thus different column diagnostic procedures may be required. See Table 9-1, Table 9-2, and Table 9-3 for a typical steering column diagnosis.

TABLE 9-1 **AUTOMATIC TRANSMISSION—STEERING COLUMN DIAGNOSIS**

Condition	Possible Cause	Correction
Lock system—will not unlock	1. Lock bolt damaged	1. Replace lock bolt.
	2. Defective lock cylinder	2. Replace or repair lock cylinder.
	3. Damaged housing	3. Replace housing.
	4. Damaged or collapsed sector	4. Replace sector.
	5. Damaged rack	5. Replace rack.
	6. Shear flange on sector shaft collapsed	6. Replace.
Lock system—will not lock	1. Lock bolt spring broken or defective	1. Replace spring.
	2. Damaged sector tooth, or sector installed incorrectly	2. Replace, or install correctly.
	3. Defective lock cylinder	3. Replace lock cylinder.
	4. Burr on lock bolt or housing	4. Remove burr.
	5. Damaged housing	5. Replace housing.
	6. Transmission linkage adjustment incorrect	6. Readjust.
	7. Damaged rack	7. Replace rack.
	8. Interference between bowl and coupling (tilt)	8. Adjust or replace as necessary.
	9. Ignition switch stuck	9. Readjust or replace.
	10. Actuator rod restricted or bent	10. Readjust or replace.
Lock system—high effort	1. Lock cylinder defective	1. Replace lock cylinder.
	2. Ignition switch defective	2. Replace switch.
	3. Rack preload spring broken or deformed	3. Replace spring.
	4. Burr on sector, rack, housing, support, tang of shift gate, or actuator rod coupling	4. Remove burr.
	5. Bent sector shaft	5. Replace shaft.
	6. Distorted rack	6. Replace rack.
	7. Misalignment of housing to cover (tilt)	7. Replace either or both.
	8. Distorted coupling slot in rack (tilt)	8. Replace rack.
	9. Bent or restricted actuator rod	9. Straighten, remove restriction, or replace.
	10. Ignition switch mounting bracket bent	10. Straighten or replace.
Lock cylinder—high effort between Off and Off-lock positions	1. Burr on tang of shift gate	1. Remove burr.
	2. Distorted rack	2. Replace rack.

(*Continued*)

TABLE 9-1 ***(Continued)***

Condition	Possible Cause	Correction
Sticks in Start position	1. Actuator rod deformed 2. Any high effort condition	1. Straighten or replace. 2. Check items under high effort section.
Key cannot be removed in Off-lock position	1. Ignition switch not set correctly 2. Defective lock cylinder	1. Readjust ignition switch. 2. Replace lock cylinder.
Lock cylinder can be removed without depressing retainer	1. Lock cylinder with defective retainer 2. Lock cylinder without retainer 3. Burr over retainer slot in housing cover	1. Replace lock cylinder. 2. Replace lock cylinder. 3. Remove burr.
Lock bolt hits shaft lock in Off and Park positions	Ignition switch not set correctly	Readjust ignition switch.
Ignition system—electrical system does not function	1. Defective fuse in "accessory" circuit 2. Connector body loose or defective 3. Defective wiring 4. Defective ignition switch 5. Ignition switch not adjusted properly	1. Replace fuse. 2. Tighten or replace. 3. Repair or replace. 4. Replace ignition switch. 5. Readjust ignition switch.
Switch does not actuate mechanically	Defective ignition switch	Replace ignition switch.
Switch cannot be set correctly	1. Switch actuator rod deformed 2. Sector to rack engaged in wrong tooth (tilt)	1. Repair or replace switch actuator rod. 2. Engage sector to rack correctly.
Noise in column	1. Coupling bolts loose 2. Column not correctly aligned 3. Coupling pulled apart 4. Sheared intermediate shaft plastic joint 5. Horn contact ring not lubricated 6. Lack of grease on bearings or bearing surfaces 7. Lower shaft bearing tight or frozen 8. Upper shaft tight or frozen 9. Shaft lock plate cover loose 10. Lock plate snapring not seated	1. Tighten pinch bolts to specified torque. 2. Realign column. 3. Replace coupling and realign column. 4. Replace or repair steering shaft and realign column. 5. Lubricate with Lubriplate. 6. Lubricate bearings. 7. Replace bearing. Check shaft and replace if scored. 8. Replace housing assembly. 9. Tighten three screws or, if missing, replace. CAUTION: Use specified screws (15 inch-pounds). 10. Replace snapring. Check for proper seating in groove.

	11. Defective buzzer dog cam on lock cylinder	11. Replace lock cylinder.
	12. One click when in Off-lock position and the steering wheel is moved	12. Normal condition: lock bolt is seating.
Steering shaft—high effort	1. Column assembly misaligned in vehicle	1. Realign.
	2. Improperly installed or deformed dust seal	2. Remove and replace.
	3. Tight or frozen, upper or lower bearing	3. Replace affected bearing or bearings.
	4. Flash on ID of shift tube from plastic joint	4. Replace shift tube.
High shift effort	1. Column not aligned correctly in car	1. Realign.
	2. Improperly installed dust seal	2. Remove and replace.
	3. Lack of grease on seal or bearing areas	3. Lubricate bearings and seals.
	4. Burr on upper or lower end of shift tube	4. Remove burr.
	5. Lower bowl bearing not assembled properly (tilt)	5. Reassemble properly.
	6. Wave washer with burrs (tilt)	6. Replace wave washer.
Improper transmission shifting	1. Sheared shift tube joint	1. Replace shift tube assembly.
	2. Improper transmission linkage adjustment	2. Readjust linkage.
	3. Loose lower shift lever	3. Replace shift tube assembly.
	4. Improper gate plate	4. Replace with correct part.
	5. Sheared lower shift lever weld	5. Replace tube assembly.
Lash in mounted column assembly	1. Instrument panel mounting bolts loose	1. Tighten to specifications (20 foot-pounds).
	2. Broken weld nuts on jacket	2. Replace jacket assembly.
	3. Instrument panel bracket capsule sheared	3. Replace bracket assembly.
	4. Instrument panel to jacket mounting bolts loose	4. Tighten to specifications (15 foot-pounds).
	5. Loose shoes in housing (tilt)	5. Replace.
	6. Loose tilt head pivot pins (tilt)	6. Replace.
	7. Loose shoe lock pin in support (tilt)	7. Replace.
Miscellaneous	1. Housing loose on jacket noticed with ignition in Off-lock position and a torque applied to the steering wheel	1. Tighten four mounting screws (60 inch-pounds).
	2. Shroud loose on shift bowl	2. Bend tabs on shroud over lugs on bowl.

TABLE 9-2 **MANUAL TRANSMISSION—STEERING COLUMN DIAGNOSIS**

Condition	Possible Cause	Correction
Shift lever sticking	1. Defective upper shift lever 2. Defective shift lever gate 3. Loose relay lever on shift tube 4. Wrong shift lever	1. Replace shift lever. 2. Replace shift lever gate. 3. Replace shift tube assembly. 4. Replace with current lever.
High shift effort	1. Column not aligned correctly 2. Lower bowl bearing not assembled correctly 3. Improperly installed seal 4. Wave washer in lower bowl bearing defective 5. Improper adjustment of lower shift levers 6. Lack of grease on seal, bearing areas, or levers 7. Damaged shift tube in bearing areas	1. Realign column. 2. Reassemble correctly. 3. Remove and replace. 4. Replace wave washer. 5. Readjust. 6. Lubricate seal, levers, and bearings. 7. Replace shift tube assembly.
Improper transmission shifting	Loose relay lever on shift tube	Replace shift tube assembly.

TABLE 9-3 **MANUAL TRANSMISSION—TILT COLUMN DIAGNOSIS**

Condition	Possible Cause	Correction
Housing scraping on bowl	Bowl bent or not concentric with hub	Replace bowl.
Steering wheel loose	1. Excessive clearance between holes in support or housing and pivot pin diameters 2. Defective or missing antilash spring in spheres 3. Upper bearing seat not seating in bearing 4. Upper bearing inner race seat missing 5. Loose support screws 6. Bearing preload spring missing or broken	1. Replace either or both. 2. Add spring or replace both. 3. Replace both. 4. Install seat. 5. Tighten to 60 inch-pounds. 6. Replace preload spring.
Steering wheel loose every other tilt position	Loose fit between shoe and shoe pivot pin	Replace both.
Noise when tilting column	1. Upper tilt bumper worn 2. Tilt spring rubbing in housing or dirt	1. Replace tilt bumper. 2. Lubricate.
Steering column not locking in any tilt position	1. Shoe seized on its pivot pin 2. Shoe grooves might have burrs 3. Shoe lock spring weak or broken	1. Replace shoe and pivot pin. 2. Replace shoe. 3. Replace lock spring.
Steering wheel fails to return to top tilt position	1. Pivot pins bound up 2. Wheel tilt spring defective 3. Turn signal switch wires too tight	1. Replace pivot pins. 2. Replace tilt spring. 3. Reposition wires.

Steering Linkage Diagnosis and Service

Diagnosis of Center Link, Pitman Arm, and Tie-Rod Ends

The vehicle should be raised and safety stands positioned under the lower control arms to support the vehicle weight. Use vertical hand force to check for looseness in all the pivots on the tie-rod ends and the center link. Inspect the seals on each tie-rod end and pivot on the center link or pitman arm for damage and cracks. Cracked seals allow dirt to enter the pivoted joints, which results in rapid wear. If looseness or damaged seals are found on any pivoted joint on the tie-rods and center link, these components must be replaced.

The second part of this diagnosis is done with the front wheels resting on the shop floor. If the vehicle is equipped with power steering, start the engine and allow the engine to idle with the transmission in Park and the parking brake applied. While someone turns the steering wheel one-quarter turn in each direction from the straight-ahead position, observe all the pivoted joints on the tie-rod ends and center link. This test allows the technician to check the steering linkage pivots under load. If any of the pivoted joints show a slight amount of play, they must be replaced.

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Front wheel shimmy may be defined as a consistent, fast, side-to-side movement of the front wheels and steering wheel. This movement is usually experienced at speeds above 40 mph (25 km/h), and it may occur more frequently while driving on irregular road surfaces.

Tie-Rod End Replacement

Worn tie-rod ends result in these problems:

1. Excessive steering wheel free play
2. Incorrect front wheel toe setting
3. Tire squeal on turns
4. Tread wear on front tires
5. Front wheel shimmy
6. Rattling noise on road irregularities

The cotter pin and nut must be removed prior to tie-rod end replacement. A puller is used to remove the tie-rod end from the steering arm (Figure 9-43). Tie-rod ends with rubber-encapsulated ball studs require special inspection and diagnostic procedures (Figure 9-44). On this type of tie-rod end, inspect for looseness of the ball stud in the rubber capsule and looseness of the stud and rubber capsule in the outer housing. If any looseness is present, replace the tie-rod end. Tie-rod end replacement is also necessary if there is any indication of the rubber capsule starting to come out of the outer housing.

SPECIAL TOOLS
Tie-rod end puller

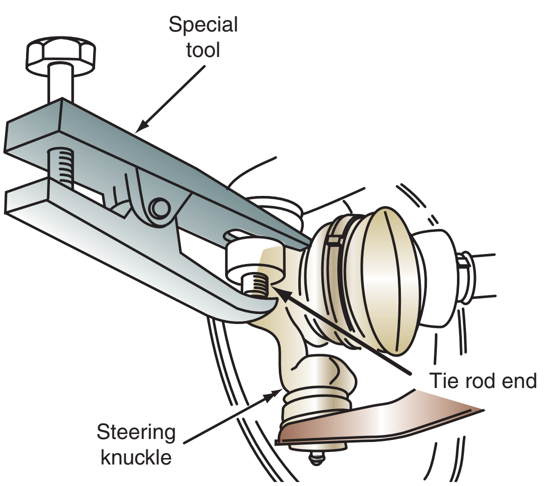


FIGURE 9-43 **Removing tie-rod end.**

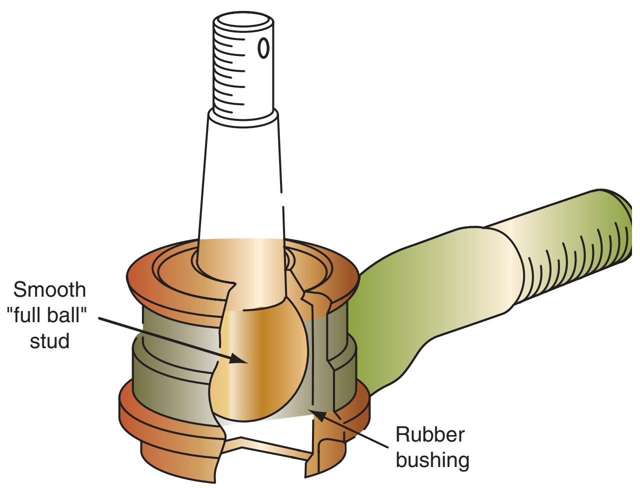


FIGURE 9-44 **Tie-rod end with rubber encapsulated ball stud.**

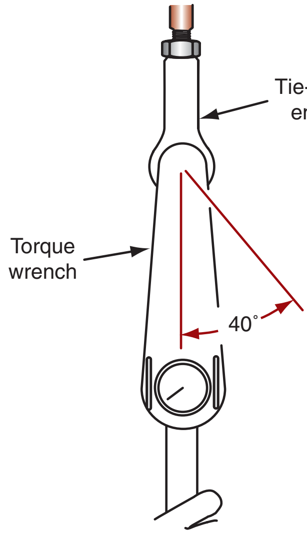


FIGURE 9-45 **Measuring turning torque on a rubber-encapsulated tie-rod end.**

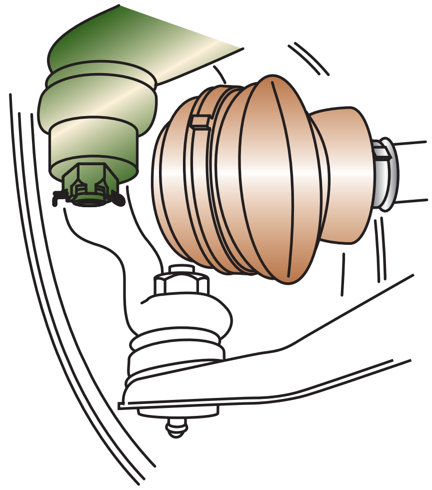


FIGURE 9-46 **Tie-rod nut and cotter pin installation.**

After the tie-rod end is removed from the steering arm, install two nuts on the stud threads and tighten these nuts against each other. Use the proper size of socket and a torque wrench to rotate the ball stud through a 40° arc (Figure 9-45). If the ball stud turning torque is less that 20 ft-lb. (27 Nm), replace the tie-rod end.

The tie-rod clamp must be loosened before the tie-rod end is removed from the sleeve. Count the number of turns required to remove the tie-rod end from the sleeve, and install the new tie-rod with the same number of turns. Even when this procedure is followed, the toe must be checked after the steering linkage components are replaced. Before the new tie-rod end is installed, center the stud in the tie-rod end. When the tie-rod end stud is installed in the steering arm opening, only the threads should be visible above the steering arm surface. If the machined surface of the tie-rod end stud is visible above the steering arm surface, or if the stud fits loosely in the steering arm opening, this opening is worn or the tie-rod end is not correct for that application. The tie-rod end nut must be torqued to the manufacturer's specifications, and the cotter pin must be installed through the tie-rod end and nut openings (Figure 9-46). Photo Sequence 16 illustrates the procedure for removing and replacing an outer tie-rod end.

CAUTION:
If rubber-encapsulated tie-rod ends are tightened with the front wheels in any position but straight ahead, steering pull and wander may occur.

The tie-rod end nut must never be loosened from the specified torque to install the cotter pin. Another method of positioning replacement tie-rod ends is to measure the distance from the center of the tie-rod stud to the end of the sleeve prior to removal. When the new tie-rod end is installed, be sure this measurement is the same. The slots in the tie-rod sleeve must be positioned away from the opening in the sleeve clamps (Figure 9-47). Leave the sleeve clamps loose until the front wheel toe is checked, and then tighten the sleeve clamp bolts to the specified torque. A special tool is available to rotate the tie-rod sleeves and set the front wheel toe (Figure 9-48).

When rubber-encapsulated tie-rod ends are installed and tightened to the specified torque, the front wheels must be straight ahead. Tightening this type of tie-rod end with the front wheels in any other position but straight ahead may cause steering pull or wander. After rubber-encapsulated tie-rod ends are tightened to the specified torque, it is acceptable for the tie-rod end housing to be tilted to one side (Figure 9-49).

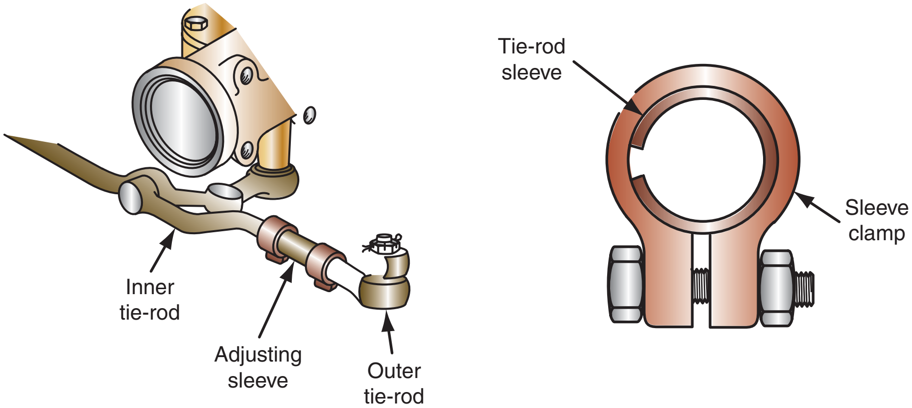


FIGURE 9-47 **Proper slot and clamp position on tie-rod sleeves.**

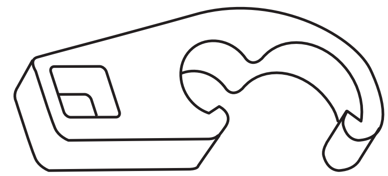


FIGURE 9-48 **Tie-rod sleeve adjusting tool.**

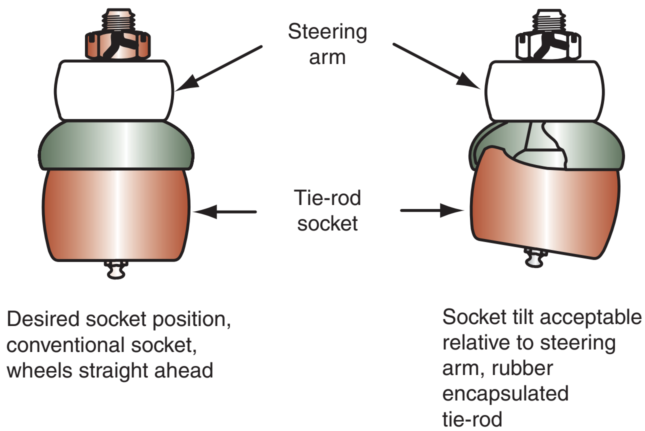


FIGURE 9-49 **Rubber-encapsulated tie-rod end housing may be tilted to one side after it is installed and tightened.**

Pitman Arm Diagnosis and Replacement

Some pitman arms contain a ball socket joint on the outer end. The threaded extension on this ball socket fits into the center link. On other steering linkages, the ball socket joint is in the center link, and the threaded extension fits into the pitman arm opening. If the pitman arm is bent, it must be replaced because the tie-rod is not parallel to the lower control arm. Under this condition, excessive front wheel toe change occurs on road irregularities, and front tire wear may be excessive.

The following is a typical pitman arm replacement procedure:

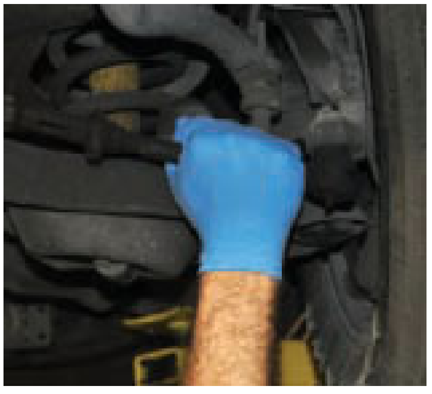
1. Position the front wheels straight ahead, and remove the cotter pin and nut from the ball socket joint on the outer end of the pitman arm.
2. Remove the ball socket extension from the pitman arm or center link with a tie-rod end puller.
3. Loosen the pitman-arm-to-pitman-shaft nut.
4. Use a puller to pull the pitman arm loose on the shaft.
5. Remove the nut, lock washer, and pitman arm.
6. Check the pitman shaft splines. If the splines are damaged or twisted, the shaft must be replaced.
7. Reverse steps 1 through 5 to install the pitman arm. The pitman arm-to-shaft nut and the ball socket extension nut must be tightened to the manufacturer's specified torque. Be sure the pitman arm is installed in the correct position on the shaft splines. Install the cotter pin in the ball socket extension.

SPECIAL TOOLS

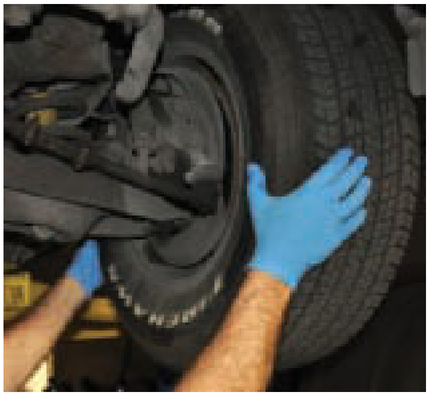
Pitman arm puller

PHOTO SEQUENCE 16

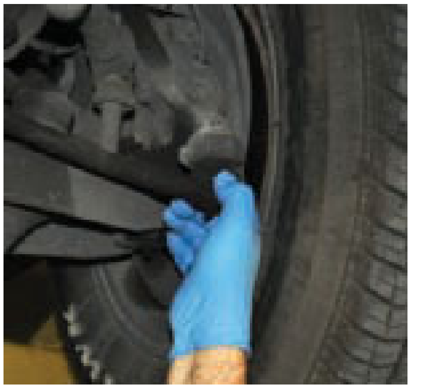
Diagnosing, Removing, and Replacing an Outer Tie-Rod End on a Vehicle with a Parallelogram Steering Linkage



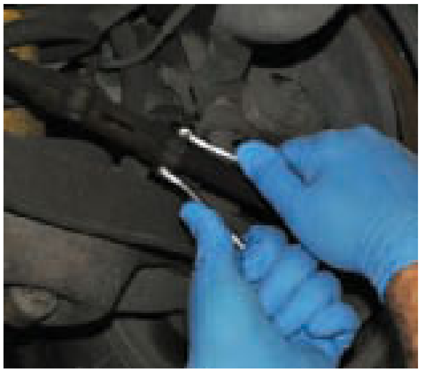
P16-1 **Raise the vehicle on a lift and check for excessive vertical movement in the left outer tie-rod end.**



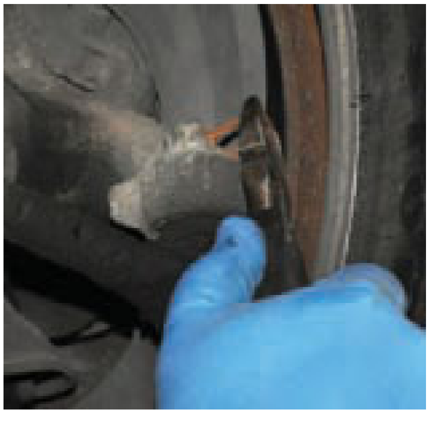
P16-2 **Check for lateral movement in the left outer tie-rod end.**



P16-3 **Visually inspect the left outer tie-rod end seal for cracks and damage.**



P16-4 **Loosen the nut on the outer bolt in the left tie-rod sleeve.**



P16-5 **Use a pair of side cutters to remove the cotter pin in the left outer tie-rod end retaining nut.**

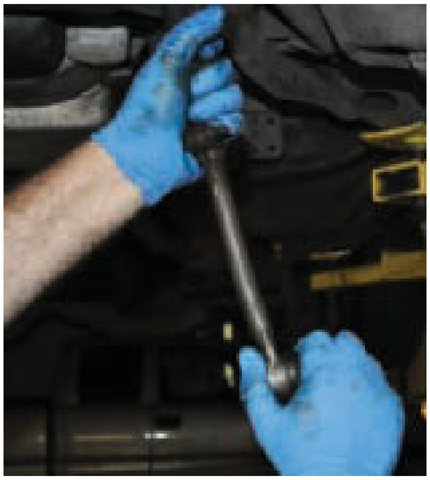
P16-6 **Use the proper size socket and ratchet to remove the retaining nut on the outer tie-rod end.**

P16-7 **Use a tape measure to carefully measure the distance from the outer edge of the left tie-rod sleeve to the outer edge of the tie-rod end, and record this distance.**

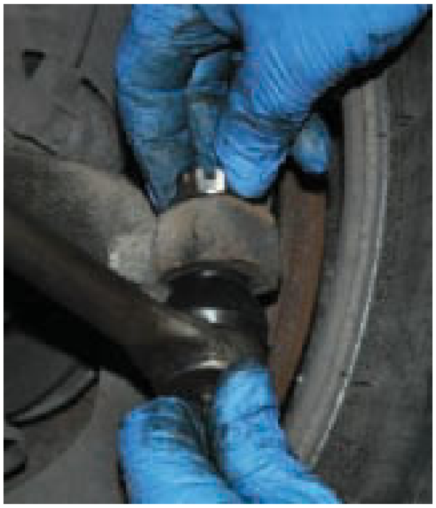
P16-8 **Install a tie-rod end puller on the left outer tie-rod end and tighten the puller bolt to remove the tie-rod end from the steering arm.**

P16-9 **After the tie-rod end is removed from the steering arm, rotate the outer tie-rod end to remove it from the from the tie-rod sleeve.**

P16-10 **Inspect the outer tie-rod sleeve for thread damage.**



P16-11 **Thread the new tie-rod end into the outer tie-rod sleeve until the distance from the outer edge of the sleeve to the outer edge of the tie-rod end is exactly the same as the original distance measured and recorded previously.**

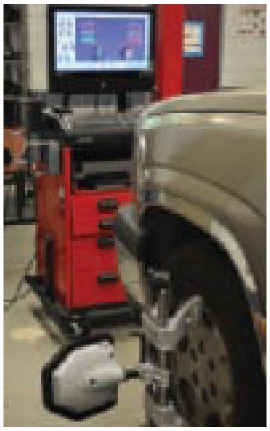


P16-12 **Be sure the seal is properly installed on the new tie-rod end, and install the outer tie-rod end in the steering arm opening and install the nut to retain the tie-rod end.**

P16-13 **Use a torque wrench and the proper size socket to tighten the left outer tie-rod nut to the specified torque. Be sure the serrated openings in the nut are aligned with the hole in the tie-rod stud.**

P16-14 **Install the cotter pin in the left outer tie-rod nut and bent the ends of this cotter pin around the nut.**

P16-15 **Position the outer tie-rod sleeve clamp so the clamp opening is positioned away from the slots in the tie-rod sleeve, and tighten the clamp bolt nut to the specified torque.**



P16-16 **Inflate all the vehicle tires to the specified pressure, and position the vehicle properly on a wheel alignment ramp. Use the wheel aligner to check the front wheel toe. Adjust the front wheel toe if necessary.**

SERVICE TIP:
Never attempt to straighten steering linkage components. This action may weaken the metal and cause sudden component failure, vehicle damage, and personal injury.

Center Link Diagnosis and Replacement

A bent center link must be replaced. Do not attempt to straighten this rod. If the ball socket joints are loose on either end of the rod, center link assembly replacement is necessary. If the ball stud openings in the center link are worn, replace the center link.

Follow these steps for a typical center link replacement:

1. Remove the cotter pins from the tie-rod-to-center-link nuts, and the idler arm and pitman-arm-to-center-link nuts.
2. Remove the nuts on the tie-rod inner ends, idler-arm-to-center-link ball socket extension, and the pitman-arm-to-center-link ball socket extension.
3. Use a tie-rod end puller to pull the inner tie-rods from the center link. Follow the same procedure to remove the center-link-to-pitman-arm ball socket extension.
4. Remove the idler arm from the center link; then remove the center link.
5. Reverse steps 1 through 4 to install the center link. Tighten all the ball socket nuts to the manufacturer's specified torque, and install cotter pins in all the nuts. If the ball sockets have grease fittings, lubricate the ball sockets with a grease gun and chassis lubricant.

Idler Arm Diagnosis

To measure idler arm vertical movement, attach the magnetic base of a dial indicator to the frame near the idler arm. Position the dial indicator stem against the upper side on the outer end of the idler arm. Preload the dial indicator stem and zero the dial. Use a pull scale to apply 25 lbs. (11.34 kg) of force downward and upward on the idler arm (Figure 9-50). Observe the total vertical idler arm movement on the dial indicator. If this vertical movement exceeds the vehicle manufacturer's specifications, replace the idler arm. Typical maximum vertical idler arm movement from the downward to the upward position is 0.250 in. (63.5 mm). If idler arm vertical movement is excessive, the tie-rod is not parallel to the lower control arm.

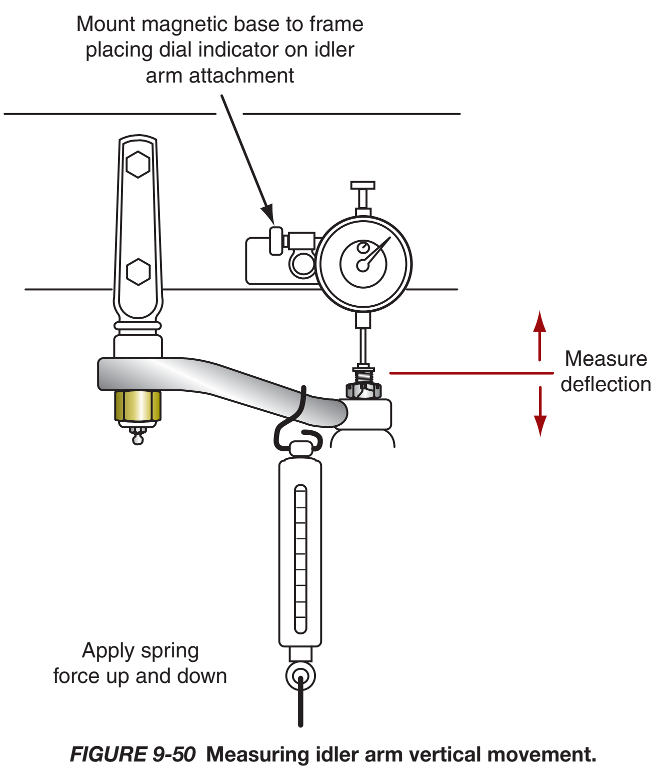


FIGURE 9-50 **Measuring idler arm vertical movement.**

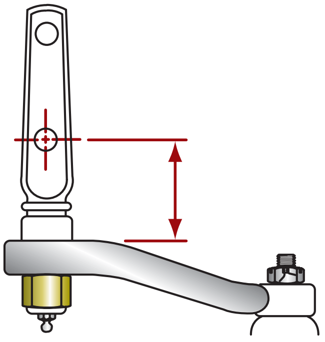


FIGURE 9-51 **Specified clearance between center of lower bracket bolt hole and upper idler arm surface.**

Excessive idler arm vertical movement causes these steering problems:

1. Excessive toe change and front tire tread wear
2. Excessive steering wheel free play and reduced steering control
3. Front end shimmy

Binding idler arm bushings result in these complaints:

1. Hard steering
2. Squawking noise when the front wheels are turned
3. Poor steering wheel returnability

Some idler arms contain steel bushings, whereas others are equipped with rubber bushings.

SERVICE TIP: A binding idler arm may suddenly break off and cause complete loss of steering control, vehicle damage, and personal injury.

The following is a typical idler arm removal and replacement procedure:

1. Remove the idler-arm-to-center-link cotter pin and nut.
2. Remove the center link from the idler arm.
3. Remove the idler arm bracket mounting bolts, and remove the idler arm.
4. If the idler arm has a steel bushing, thread the bracket into the idler arm bushing until the specified clearance is obtained between the center of the lower bracket bolt hole and the upper idler arm surface (Figure 9-51).
5. Install the idler arm bracket to frame bolts, and tighten the bolts to the specified torque. Be sure that lock washers are installed on the bolts.
6. Install the center link into the idler arm, and tighten the mounting nut to the specified torque. Install the cotter pin in the nut.
7. If the idler arm contains a grease fitting, lubricate as required.

The idler arm adjustment is very important. If this adjustment is incorrect, front wheel toe is affected. After idler arm replacement, the front wheel toe should be checked.

Steering Damper Diagnosis and Replacement

Some steering systems have a damper connected between the center link and the chassis. A damper is similar to a small shock absorber. The purpose of the damper is to prevent the transfer of steering shock and vibrations to the steering wheel. A worn-out steering damper may cause excessive steering shock and vibration on the steering wheel, especially on irregular road surfaces. A rattling noise occurs if the damper mounting bolts or brackets are loose.

The following is a typical steering damper checking and replacement procedure:

1. Lift the vehicle on a hoist, and grasp the damper firmly. Apply vertical and horizontal pressure to the damper, and check for movement in the damper mounts. If movement exists, tighten or replace the damper mounting bushings or brackets.

2. Visually inspect the damper for oil leaks. A slight film of oil on the damper body near the shaft seal is acceptable. If there is any indication of oil dripping from the damper, the unit must be replaced.
3. Disconnect one end of the damper, and pull the damper back and forth horizontally. The damper should offer a slight equal resistance to movement in either direction. When this resistance is not felt in one or both directions, replace the damper.
4. To replace the damper, remove the mounting bolts from the chassis and the center link.
5. When the new damper is installed, tighten the mounting bolts to the specified torque. Turn the steering wheel fully in each direction, and be sure the damper does not restrict linkage movement.

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Steering Arm Diagnosis

If the front rims have been damaged, the steering arms should be checked for a bent condition. Measure the distance from the center of the tie-rod end stud to the edge of the rim on each side. Unequal readings may indicate a bent steering arm. Bent steering arms must be replaced. Steering linkage diagnosis is summarized in Table 9-4.

TABLE 9-4 **STEERING LINKAGE DIAGNOSIS**

Condition	Possible Cause	Correction
Excessive play or looseness in steering system	1. Front wheel bearings loosely adjusted	1. Adjust bearings to obtain proper endplay.
	2. Worn steering shaft couplings	2. Replace part.
	3. Worn upper ball joints	3. Check and replace if necessary.
	4. Steering wheel loose on shaft or loose pitman arm, tie-rods, steering arms, or steering linkage ball studs	4. Tighten to specified torque, or replace if necessary.
	5. Steering gear thrust bearings loosely adjusted	5. Adjust preload to specifications.
	6. Excessive over-center lash in steering gear	6. Adjust preload to specifications per shop manual.
	7. Worn intermediate rod or tie-rod sockets	7. Replace worn part.
Excessive looseness in tie-rod or intermediate rod pivots, or excessive vertical lash in idler support	Seal damage and leakage resulting in loss of lubricant, corrosion, and excessive wear	Replace damaged parts as necessary. Properly position upon reassembly.
Hard steering—excessive effort required at steering wheel	1. Low or uneven tire pressure	1. Inflate to specified pressures.
	2. Steering linkage or bolt joints need lubrication	2. Lube with specified lubricant.
	3. Tight or frozen intermediate rod, tie-rod, or idler socket	3. Lube, replace, or reposition as necessary.
	4. Steering gear-to-column misalignment	4. Align column.
	5. Steering gear adjusted too tightly	5. Adjust over-center and thrust bearing preload to specification.
	6. Front wheel alignment incorrect (manual gear)	6. Check alignment and correct as necessary.

(Continued)

TABLE 9-4 *(Continued)*

Condition	Possible Cause	Correction
Poor returnability	1. Steering linkage or ball joints need lubrication	1. Lube with specified lubricant.
	2. Steering gear adjusted too tightly	2. Adjust over-center and thrust bearing preload to specifications.
	3. Steering gear-to-column misalignment	3. Align columns.
	4. Front wheel alignment incorrect (caster)	4. Check alignment and correct as necessary.

CASE STUDY

A customer complained about excessive steering effort and poor steering wheel returnability after a turn on a 2009 General Motors Sierrra truck with power steering. The technician road tested the car and found the customer's description of the problems to be accurate except for one point. The steering continually required excessive steering effort, and the steering wheel did not return properly after a turn. However, the customer did not mention, or possibly did not notice, that a squawking and creaking noise was sometimes heard during a turn.

The technician checked the power steering fluid level and condition, and found this fluid to be in good condition and at the proper level. Next, the technician checked the power steering belt condition and the power steering pump pressure. The belt tension and condition were satisfactory, and the power steering pump pressure was normal. A check of the power steering pump mounting bolts and brackets indicated they were in good condition. The technician disconnected the center link from the pitman arm and rotated the steering wheel with the engine running. Under this condition, the steering wheel turned very easily. Therefore, the technician concluded the excessive steering effort and poor returnability problems were not in the steering column or steering gear. Next, the technician disconnected the idler arm from the center link. When the technician attempted to move the idler arm back and forth, the idler arm had a severe binding problem. After an idler arm replacement, a road test revealed the excessive steering effort and poor returnability problems had disappeared.

Terms to Know

Accidental air bag deployment
Air bag deployment module
Backup power supply
Clock spring electrical connector
Collapsible steering column
Molybdenum disulphide lithium-based grease
Sheared injected plastic
Steering wheel free play
Tapered-head bolts

ASE-Style Review Questions

1. While discussing steering column service on an air-bag-equipped vehicle:

   Technician A says service personnel should disconnect the negative battery cable and wait one minute prior to servicing an air bag system component.

   Technician B says a 12-V test lamp may be used to diagnose an air bag system.

   Who is correct?

   A. A only　　C. Both A and B
   B. B only　　D. Neither A nor B

2. While discussing steering column service on an air-bag-equipped vehicle:

   Technician A says an air bag deployment module should be placed face downward on the work-bench.

   Technician B says the backup power supply provides power to deploy the air bag if the battery is disconnected during a frontal collision.

   Who is correct?

   A. A only　　C. Both A and B
   B. B only　　D. Neither A nor B

3. While discussing steering wheel and clock spring electrical connector removal and replacement on an air-bag–equipped vehicle:

   Technician A says the steering may bind if the clock spring is improperly installed.

   Technician B says when the clock spring electrical connector is installed, the front wheels should be straight ahead, and the clock spring should be turned fully clockwise.

   Who is correct?

   A. A only　　C. Both A and B
   B. B only　　D. Neither A nor B

4. While discussing steering wheel removal:

   Technician A says a steering wheel should be marked in relation to the steering shaft.

   Technician B says the steering wheel should be grasped firmly with both hands and pulled from the shaft.

   Who is correct?

   A. A only C. Both A and B

   B. B only D. Neither A nor B

5. While discussing collapsible steering column damage:

   Technician A says if the vehicle has been in a frontal collision, the injected plastic in the column jacket, gearshift tube, and steering shaft may be sheared.

   Technician B says after a collision, some steering columns may be shifted on the bracket.

   Who is correct?

   A. A only C. Both A and B

   B. B only D. Neither A nor B

6. All of these statements about steering column service are true EXCEPT:

   A. Many ignition switches must be in the ACC position before removing the switch cylinder.

   B. An improperly installed dust seal may cause excessive steering wheel free play.

   C. High steering effort may be caused by an improperly aligned steering column.

   D. A worn steering shaft universal joint may cause excessive steering wheel free play.

7. A rattling noise in the steering column and linkage may be caused by:

   A. A bent center link.

   B. A binding idler arm.

   C. A worn steering shaft U-joint.

   D. Loose tie-rod sleeve clamps.

8. When diagnosing and servicing tie-rod ends:

   A. Rubber-encapsulated tie-rod ends should be tightened with the wheels turned fully to the right or left.

   B. The machined part of the tie-rod stud should be visible above the surface of the steering arm.

   C. The nut on the tie-rod stud may be loosened to install the cotter pin.

   D. If the turning torque on a rubber-encapsulated tie-rod end is less than specified, the tie-rod end must be replaced.

9. When diagnosing and servicing steering linkages:

   A. A worn tie-rod end causes excessive front wheel toe change.

   B. Bent steering linkages may be straightened in a hydraulic press.

   C. The slot in a tie-rod sleeve clamp must be positioned above the slot in the tie-rod sleeve.

   D. Front wheel shimmy may be caused by a binding idler arm.

10. An idler arm has 5/8 in. (15.8 mm) vertical movement. To correct this problem it is necessary to:

   A. Install thicker shims between the idler arm and the bracket.

   B. Install an oversize bushing in the idler arm.

   C. Replace the idler arm assembly.

   D. Replace the Belleville washer and spacer under the bushing.

ASE Challenge Questions

1. A preliminary steering inspection reveals that the steering wheel has nearly 1/2 inch of movement in either direction before the pitman arm begins to move. All of the following could cause this problem EXCEPT:

   A. Coupling joints.

   B. U joints.

   C. Tight or seized shaft bearing.

   D. Worn or out-of-adjustment steering gear.

2. A customer complains that sometimes the ignition switch won't unlock and the key won't turn. A preliminary inspection reveals that turning the steering wheel does not help but repositioning the key, after several attempts, unlocks the ignition.

   Technician A says the problem could be the column assembly is misaligned.

   Technician B says the problem could be the ignition key is worn.

   Who is correct?

   A. A only C. Both A and B

   B. B only D. Neither A nor B

3. If the clock spring electrical connector is not properly centered before it is installed:
   A. The steering may pull to one side.
   B. The clock spring electrical connector may be broken.
   C. The air bag may deploy without the vehicle being in an accident.
   D. The steering may have a binding condition.

4. A customer says the steering on his vehicle is very hard to turn in both directions. A preliminary inspection reveals no problems with the manual rack and pinion steering gear.

   Technician A says the problem could be a misaligned steering column.

   Technician B says the problem could be tight or frozen tie-rod ends.

   Who is correct?

A. A only	C. Both A and B
B. B only	D. Neither A nor B

5. A customer says his steering has a shimmy problem above 50 mph (80 km/h). Preliminary inspection indicates excessive wear on the right front tire.

   Technician A says the problem could be a worn tie-rod end.

   Technician B says the problem could be a worn idler arm ball joint.

   Who is correct?

A. A only	C. Both A and B
B. B only	D. Neither A nor B

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Name ______________________________ Date ____________________

Remove and Replace Air Bag Inflator Module and Steering Wheel

Upon completion of this job sheet, you should be able to remove and replace an air bag inflator module and steering wheel.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-1, B-2. Disable and enable supplemental restraint system (SRS). Remove and replace steering wheel, center/time supplemental restraint system (SRS) coil block spring.

Tools and Materials

Steering wheel puller

Torque wrench

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ______________________________

VIN ______________________________ Engine type and size ______________________

Procedure

Task Completed

1. Turn the ignition switch to the Lock position and place the front wheels facing straight ahead. ☐
2. Remove the negative battery terminal and wait the time period specified by the vehicle manufacturer before servicing air bag components.

   Specified waiting period ____________

   After the negative battery cable is disconnected, explain why a waiting period is necessary before working on the air bag system.

   ____

   ____

   ____

   ____

3. Loosen the air bag retaining screws under the steering wheel. ☐
4. Loosen the other two air bag retaining screws under the steering wheel. ☐

   Loosen all the screws until the groove along the screw circumference catches on the screw case.

WARNING: When an air bag deployment module is temporarily stored on the workbench, always place this module face upward. If the air bag deployment module accidentally deployed when facing downward, the module would become a projectile and personal injury may result.

Task Completed

☐ 5. Pull the air bag deployment module from the steering wheel, and disconnect the air bag module electrical connector. Do not pull on the air bag wires in the steering column. Place the air bag deployment module face upward on the workbench.

☐ 6. Disconnect the air bag wiring retainer in the steering wheel.

☐ 7. Use the proper size socket and a ratchet to remove the steering wheel retaining nut.

☐ 8. Observe the matching alignment marks on the steering wheel and the steering shaft. If these alignment marks are not present, place alignment marks on the steering wheel and steering shaft with a center punch and a hammer.

Alignment marks on steering wheel and steering shaft:
☐ Satisfactory ☐ Unsatisfactory

WARNING: Do not pull on the steering wheel in an attempt to remove it from the steering shaft. The steering wheel may suddenly come off, resulting in personal injury, or the steering wheel may be damaged by the pulling force.

☐ 9. Install a steering wheel puller with the puller bolts threaded into the bolt holes in the steering wheel. Tighten the puller nut to remove the steering wheel. Visually check the steering wheel condition. If the steering wheel is bent or cracked, replace the wheel.

Steering wheel condition: ☐ Satisfactory ☐ Unsatisfactory

☐ 10. Disconnect the four retaining screws, and remove the clock spring electrical connector.

☐ 11. Be sure the front wheels are facing straight ahead. Turn the clock spring electrical connector counterclockwise by hand until it becomes harder to turn as it becomes fully wound in that direction.

CAUTION: Do not hammer on the top of the steering shaft to remove the steering wheel. This action may damage the shaft.

12. Turn the clock spring electrical connector clockwise three turns, and align the red mark on the center part of the spring face with the notch in the cable circumference. This action centers the clock spring electrical connector.

Is the clock spring centered? ☐ Yes ☐ No

Instructor check ______________________________

Explain why the clock spring electrical connector must be centered before it is installed.

____

____

____

☐ 13. Install the clock spring electrical connector, and tighten the four retaining screws to the specified torque.

14. Align the marks on the steering wheel and the steering shaft, and install the steering wheel on the shaft.

Are the marks on the steering wheel and steering shaft aligned? ☐ Yes ☐ No

Instructor check ______________________________

Task Completed

15. Install the steering wheel retaining nut, and tighten this nut to the specified torque.

Specified steering wheel retaining nut torque ____________

Actual steering wheel retaining nut torque ____________

16. Install the air bag wiring retainer in the steering wheel. ☐

17. Hold the air bag deployment module near the top of the steering wheel, and connect the air bag module connector. ☐

18. Install the air bag deployment module in the top of the steering wheel, and tighten the retaining screws. ☐

19. Reconnect the negative battery cable. ☐

20. Reset the clock and radio. ☐

21. Turn on the ignition switch and start the vehicle. Check the operation of the air bag system warning light. ☐

Explain the air bag system warning light operation that indicates normal air bag system operation.

____

____

____

Instructor's Response ____

____

____

CAUTION:
Failure to center a clock spring prior to installation may cause a broken conductive tape in the clock spring.

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Name ______________________________ Date ____________________

Remove and Replace Steering Column

Upon completion of this job sheet, you should be able to remove and replace a steering column.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-3: Diagnose steering column noises, looseness, and binding concerns (including tilt mechanisms), determine necessary action.

Tools and Materials

Seat cover

Torque wrench

Describe the Vehicle Being Worked On:

Year ________ Make ______________ Model ________________________

VIN ________________________ Engine type and size ___________________

Procedure

Task Completed

1. Disconnect the negative battery cable. If the vehicle is equipped with an air bag, wait for the time period specified by the vehicle manufacturer.

   Specified waiting period prior to servicing air bag components ________

   Explain why it is necessary to disconnect the battery before removing the steering column.

   ____

   ____

   ____

2. Install a seat cover on the front seat. ☐
3. Place the front wheels in the straight-ahead position and remove the ignition key from the switch to lock the steering column.

   Are the front wheels straight? ☐ Yes ☐ No

   Is the ignition key removed?

   Instructor check ______________________________ ☐
4. Remove the cover under the steering column and remove the lower finish panel if necessary. ☐
5. Disconnect all wiring connectors from the steering column. ☐
6. If the vehicle has a column-mounted gearshift lever, disconnect the gearshift linkage at the lower end of the steering column. ☐

Task Completed

☐ 7. Remove the retaining bolt or bolts in the lower universal joint or flexible coupling.

☐ 8. Remove the steering-column-to-instrument-panel mounting bolts.

☐ 9. Carefully remove the steering column from the vehicle. Be careful not to damage the upholstery or paint.

☐ 10. Install the steering column under the instrument panel and insert the steering shaft into the lower universal joint.

11. Install the steering column to instrument panel mounting bolts. Be sure the steering column is properly positioned, and tighten these bolts to the specified torque.

Specified torque, steering column mounting bolts ____________

Actual torque, steering column mounting bolts ____________

12. Install the retaining bolt or bolts in the lower universal joint or flexible coupling, and tighten the bolt(s) to the specified torque.

Specified torque, lower U-joint retaining bolt(s)____________

Actual torque, lower U-joint retaining bolt(s) ____________

☐ 13. Connect the gearshift linkage if the vehicle has a column-mounted gearshift.

☐ 14. Connect all the wiring harness connectors to the steering column connectors.

☐ 15. Install the steering column cover and the lower finish panel.

☐ 16. Reconnect the negative battery cable.

☐ 17. Road test the vehicle, and check for proper steering column operation.

Steering column operation: ☐ Satisfactory ☐ Unsatisfactory

Instructor's Response ____

____

____

Name ______________________________ Date ____________________

Diagnose, Remove, and Replace Idler Arm

Upon completion of this job sheet, you should be able to diagnose, remove, and replace an idler arm.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-17: Inspect and replace pitman arm, relay (centerlink/intermediate) rod, idler arm and mountings, steering linkage damper.

Tools and Materials

Pull scale
Dial indicator
Torque wrench
Grease gun

Describe the Vehicle Being Worked On:

Year ________ Make ________________ Model ______________________
VIN ________________________ Engine type and size ____________________

Procedure

Task Completed

1. Attach the magnetic base of a dial indicator to the frame near the idler arm. ☐
2. Position the dial indicator stem against the upper side on the outer end of the idler arm. Preload the dial indicator stem, and zero the dial. ☐
3. Use a pull scale to apply 25 lbs. (11.34 kg) of force downward and then upward on the idler arm. Observe the total vertical idler arm movement on the dial indicator. If this vertical movement exceeds the vehicle manufacturer's specifications, replace the idler arm.

   Specified vertical idler arm movement __________

   Actual vertical idler arm movement __________

   Recommended idler arm service __________

   Explain the effect of idler arm wear on steering quality.

   ____

   ____

   ____

4. Remove the idler arm to center link cotter pin and nut. ☐
5. Remove the center link from the idler arm. ☐

Task Completed

6. Remove the idler arm bracket mounting bolts and remove the idler arm.

☐ 7. If the idler arm has a steel bushing, thread the bracket into the idler arm bushing until the specified clearance is obtained between the center of the lower bracket bolt hole and the upper idler arm surface.

Specified distance from center of lower bracket hole to upper idler arm surface

____

Actual distance from center of lower bracket hole to upper idler arm surface

____

8. Install the idler arm bracket to frame bolts and tighten the bolts to the specified torque. Be sure that lock washers are installed on the bolts.

Specified idler arm retaining bolt torque ____________

Actual idler arm retaining bolt torque ____________

9. Install the center link into the idler arm and tighten the mounting nut to the specified torque. Install the cotter pin in the nut.

Specified center link to idler arm retaining nut torque ____________

Actual center link to idler arm retaining nut torque ____________

☐ 10. If the idler arm has a grease fitting, lubricate as required.

Instructor's Response ____

____

____

Name ______________________________ Date ____________________

Remove and Replace Outer Tie-Rod End, Parallelogram Steering Linkage

Upon completion of this job sheet, you should be able to remove and replace outer tie-rod ends in a parallelogram steering linkage.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-18: Inspect, replace, and adjust tie rod ends (sockets) tie rod sleeves, and clamps.

Tools and Materials

Tie-rod puller

Describe the Vehicle Being Worked On:

Year ________ Make ________________ Model ______________________

VIN ________________________ Engine type and size ____________________

Procedure

1. Raise the vehicle on a lift with the tires supported on the lift. If the vehicle has rubber-encapsulated tie-rod ends, be sure the front wheels are straight ahead.
2. Loosen the nut on the tie-rod sleeve bolt that retains the sleeve to the tie-rod ends.
3. Measure from the top center of the tie-rod end ball stud to the outer end of the tie-rod sleeve, and record the measurement.
   Distance from the center of the tie-rod end ball stud to the outer end of the tie-rod sleeve __________
4. Remove the cotter pin from the tie-rod end retaining nut.
5. Loosen the tie-rod end retaining nut.
6. Use a tie-rod end puller to loosen the tie-rod end taper in the steering arm.
7. Remove the tie-rod end retaining nut and remove the tie-rod end from the steering arm.
8. Count the number of turns required to thread the tie-rod end out of the tie-rod sleeve.

   Number of turns required to remove the tie-rod end from the tie-rod sleeve

   ____

   Describe the effect of worn, loose outer tie-rod ends on steering quality.

   ____

   ____
9. Install the new tie-rod end in the tie-rod sleeve using the same number of turns recorded in step 8.

10. Push the tie-rod end ball stud fully into the steering arm opening. Only the threads on the tie-rod end ball stud should be visible above the steering arm surface.

Is the taper on the tie-rod end ball stud visible above the steering arm surface?
☐ Yes ☐ No

If the answer to this question is yes, state the necessary repairs required to correct this problem.

____

____

Instructor check ______________________________

11. With the tie-rod end ball stud pushed fully upward into the steering arm, measure the distance from the center of the ball stud to the outer end of the tie-rod sleeve.

Distance from the center of the tie-rod end ball stud to the outer end of the tie-rod sleeve

____

12. If this distance is not the same as recorded in step 3, remove the tie-rod end ball stud from the steering arm, and rotate the tie-rod end until this distance is the same as recorded in step 3.

13. Install the tie-rod end ball stud retaining nut, and tighten this nut to the specified torque.

Specified ball stud nut torque ____________

Actual ball stud nut torque ____________

WARNING: Never loosen a tie-rod end ball stud nut to align the openings in the ball stud and nut to allow cotter pin installation. This action may cause the nut to loosen during operation of the vehicle, and this will result in excessive steering free play. Complete loss of steering control will occur if the nut comes off the tie-rod end ball stud, and this may cause a collision.

14. Install a new cotter pin through the tie-rod end ball stud and nut openings, and bend the cotter pin legs separately around this nut.

15. Tighten the nut on the outer tie-rod sleeve clamp bolt to the specified torque. Be sure the slot in the tie-rod sleeve is positioned away from the opening in the clamp.

16. Measure the front wheel toe with a toe bar.

Specified front wheel toe ____________

Actual front wheel toe ____________

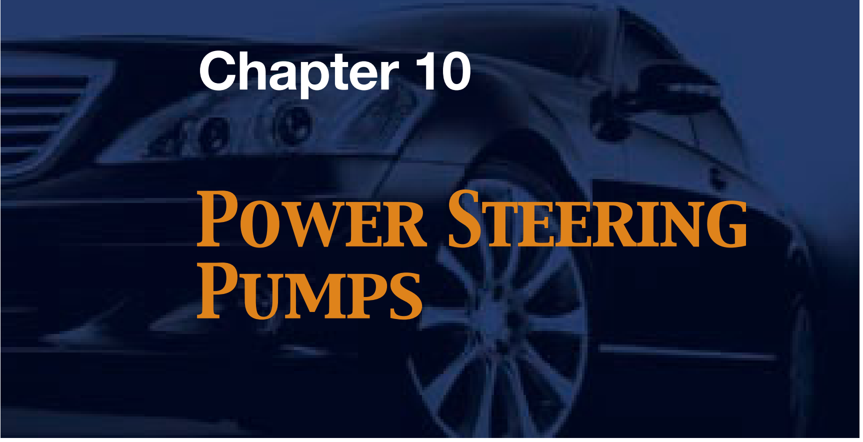
Explain the type of front tire wear that is caused by improper front wheel toe.

____

Instructor's Response ______________________________

____

____



Chapter 10

Power Steering Pumps

Upon completion and review of this chapter, you should be able to understand and describe:

- The difference between a conventional V-belt and a serpentine belt.
- The advantages of a serpentine belt compared with a conventional V-belt.
- The main components in a power-assisted rack and pinion steering system, and explain the steering gear mounting position.
- Two different types of power steering pump reservoirs.
- The difference between a hydroboost power steering system and an integral power steering system.
- Three different types of power steering pump rotor designs.
- The power steering pump operation while driving with the front wheels straight ahead.
- The power steering pump operation while the vehicle is turning a corner.
- The power steering pump pressure relief operation, and explain when this operation occurs.
- The design and purpose of an electrohydraulic power steering module.
- Electrohydraulic power steering (EHPS) systems.
- Hybrib electric vehicle (HEV) operation.

Introduction

Power steering systems have contributed to reduced driver fatigue and made driving a more pleasant experience. Nearly all power steering systems at the present time use fluid pressure to assist the driver in turning the front wheels. Since driver effort required to turn the front wheels is reduced, driver fatigue is decreased. The advantages of power steering have been made available on many vehicles, and safety has been maintained in these systems.

There are several different types of power steering systems, including integral, rack and pinion, hydroboost, and linkage type. In any of these systems, the power steering pump is the heart of the system because it supplies the necessary pressure to assist steering.

The power steering pump drive belt is a simple, but very important, component in the power steering system. A power steering pump in perfect condition will not produce the required pressure for steering assist if the drive belt is slipping. Various types of steering systems, drive belts, and pump designs are described in this chapter.

Power Steering Pump Drive Belts

Many power steering pumps are driven by a **V-belt** that surrounds the crankshaft pulley and the power steering pump pulley. The V-belt may also drive other components, such as the water pump. The sides of a V-belt are the friction surfaces that drive the power steering pump (Figure 10-1). If the sides of the belt are worn and the lower edge of the belt is contacting the bottom of the pulley, the belt will slip. The power steering pump pulley, crankshaft pulley, and any other pulleys driven by the V-belt *must be properly aligned.* If these pulleys are misaligned, excessive belt wear occurs.

WARNING: Always keep hands, tools, and equipment away from rotating belts and pulleys. If any of these items become entangled in rotating belts, personal injury and equipment damage may result.

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WARNING: Always keep long hair tied back while working in the automotive shop! If long hair is entangled in rotating belts and pulleys, personal injury will result.

A serpentine belt is used on many vehicles, and this belt may be used to drive all the belt-driven components. The serpentine belt is much wider than a conventional V-belt, and the underside of the belt has a number of small ribbed grooves. Most serpentine belts have spring-loaded automatic belt tensioners that eliminate periodic belt tension adjustments. Since the serpentine belt may be used to drive all the belt-driven components, these components are placed on the same vertical plane, which saves a considerable amount of underhood space (Figure 10-2). The smooth backside of the serpentine belt may also be used to drive one of the components. Regardless of the type of belt, the belt tension is critical. A power steering pump will never develop full pressure if the belt is slipping.

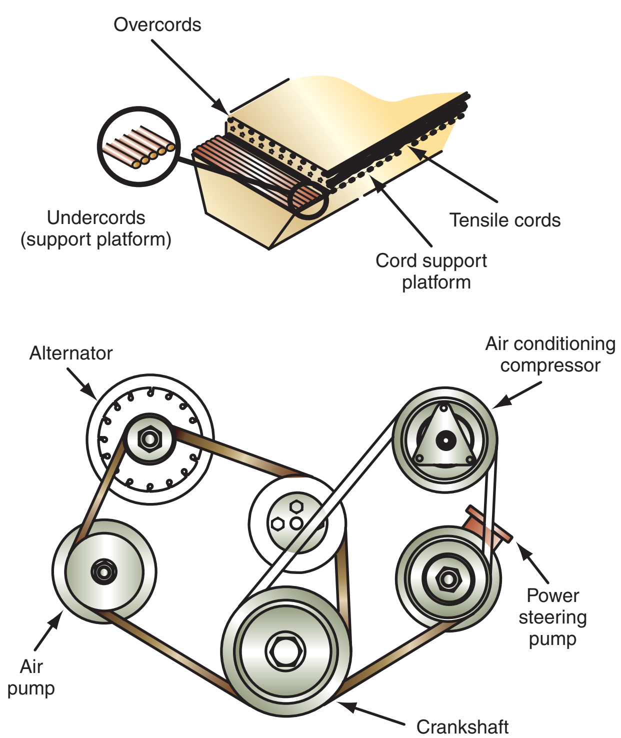

FIGURE 10-1 **Conventional V-belt.**

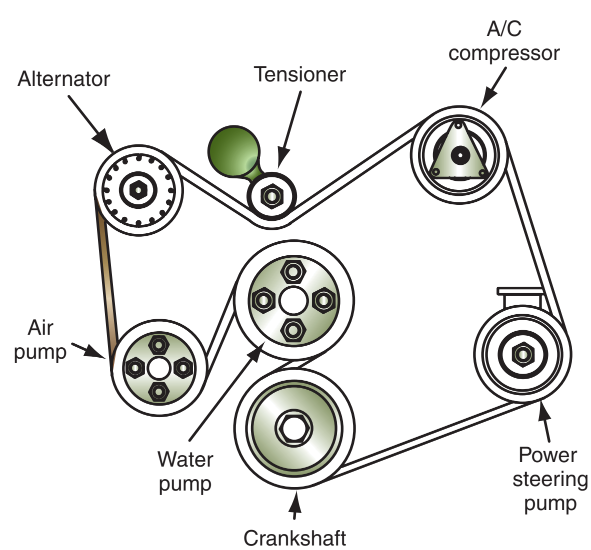

FIGURE 10-2 **Serpentine belt.**

AUTHOR'S NOTE: It has been my experience that the most common cause of power steering pump complaints is the pump drive belt. A loose, worn, or dry belt may cause a chirping noise at idle or squealing during acceleration. A loose or worn belt may cause a humming-type vibration noise. Intermittent or continual hard steering may be caused by a loose pump drive belt. A loose power steering pump belt may even cause a complaint of hard steering when driving on wet days, because the belt has more tendency to slip when it is wet. A loose belt may cause low power steering pump pressure when testing the pump. Therefore, when diagnosing power steering pump problems, you should always inspect the pump drive belt and measure the belt tension before any other diagnostic tests are performed.

Some current vehicles are equipped with a stretchy belt that does not require a belt tensioner or belt adjustment. The stretchy belt has a similar appearance compared to a conventional serpentine belt. However, stretchy belts have tensile cords made from a polyamide material that is three times more elastic compared with the cords in a conventional serpentine belt. In a stretchy belt, the rubber layers around the cord layer have superior durability and improved adhesion to the cord layer to accommodate the stretching action. Eliminating the mechanical belt tensioner saves weight, space, and financial cost. The stretchy belt is usually installed only around two pulleys such as the A/C compressor and crankshaft pulleys, and the remaining belt-driven components have a conventional V-belt drive.

If a stretchy belt requires replacement, the vehicle manufacturer recommends cutting the old belt to remove it. A special tool is used to lift and guide the new stretchy belt onto the pulley.

A **remote reservoir** is mounted externally from the power steering pump.

TYPES OF POWER-ASSISTED STEERING SYSTEMS

Rack and Pinion Steering System

In an **integral power-assisted steering system**, the control valve and power cylinder are contained in the steering gear.

The **rack and pinion power steering system** is used on most front-wheel-drive cars. In this steering system, the power steering pump is bolted to a bracket on the engine, and the pump is driven by a belt from the crankshaft. In most front-wheel-drive cars, the engine is mounted transversely, and the steering gear is mounted on the cowl behind the engine or on the crossmember below the engine (Figure 10-3).

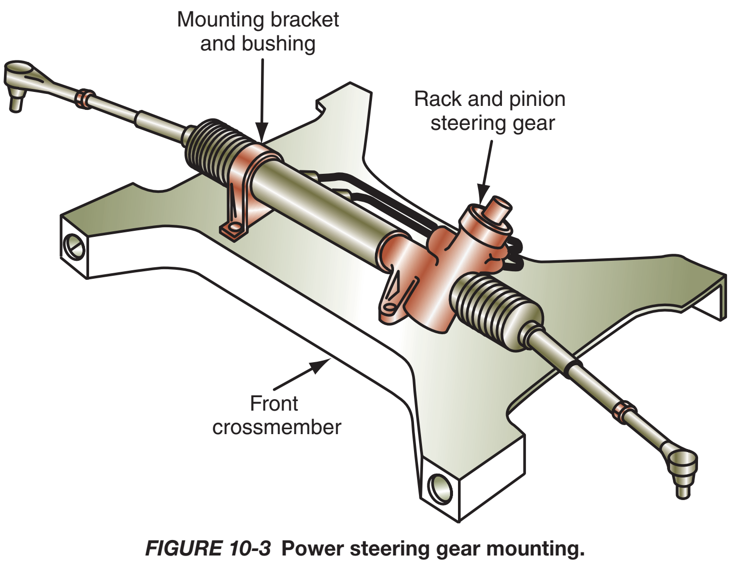

FIGURE 10-3 **Power steering gear mounting.**

FIGURE 10-4 **Power steering reservoir and dipstick.**

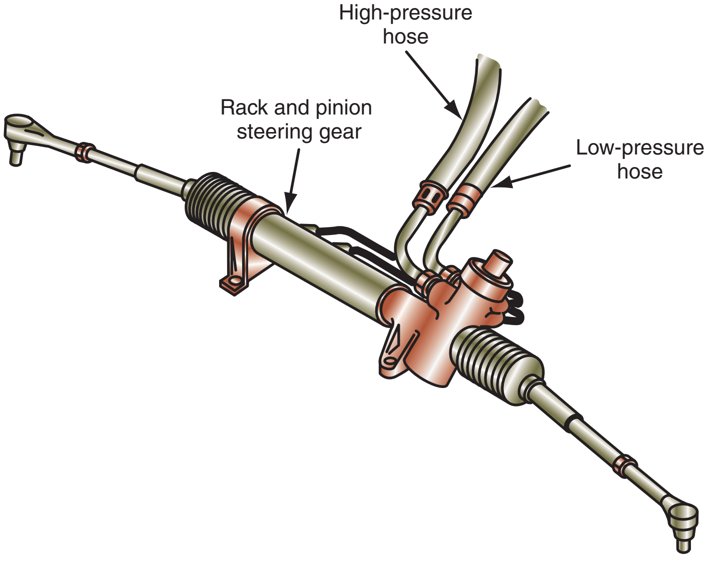

FIGURE 10-5 **Power steering pump to gear hoses.**

In many power-assisted rack and pinion steering systems, an **integral reservoir** is part of the power steering pump. A dipstick is mounted in the reservoir for fluid level checking (Figure 10-4). A high-pressure hose and a low-pressure return hose are connected from the pump to the steering gear (Figure 10-5). The high-pressure hose is usually a steel-braided hose with appropriate fittings in each end. The return hose is a rubber-braided hose that is clamped to the fittings on the pump and gear.

Some power-assisted rack and pinion steering systems have a **remote reservoir**. This type of system is commonly used on small cars with limited underhood space where it may be difficult to access an integral reservoir on the power steering pump. The remote reservoir is placed in a convenient position, and the return hose is connected from the steering gear to the reservoir. A second return hose is routed from the reservoir to the pump (Figure 10-6).

A Bit of History

The number of independent automotive repair facilities and the number of individuals employed by these shops has increased steadily in the last decade. In 1995 there were 63,844 independent automotive mechanical repair facilities in the United States, and they employed 244,430 workers. In 2004 the independent mechanical repair facilities in the United States totaled 79,695, and they employed 318,186 individuals.

Integral Power-Assisted Steering System

In the **integral power-assisted steering system**, the pump is bolted to a bracket on the engine, and the recirculating ball steering gear is mounted on the frame beside the engine. This type of steering system is used on many rear-wheel-drive cars and light-duty trucks. The pump is driven by a belt from the crankshaft and an integral reservoir is mounted on the pump. A high-pressure hose and a return hose are connected from the pump to the steering gear (Figure 10-7).

Hydroboost Power-Assisted Steering System

The **hydroboost power-assisted steering system** is used on many light-duty trucks with diesel engines and on some cars. Since the hydroboost system does not use manifold vacuum for brake assist, this system is suitable for diesel engines, which have reduced intake manifold vacuum compared with gasoline engines. The power steering on these systems is similar to an integral unit, but the power steering pump pressure is also applied to the hydroboost unit in the brake master cylinder. Hydraulic lines are routed from the power steering pump to the steering gear, and another set of lines is connected from the pump to the master cylinder (Figure 10-8). In the hydroboost system, the power steering pump pressure applied to the master cylinder pistons acts as a brake booster to assist the driver in applying the brakes. The hydroboost system does not have a conventional vacuum booster on the master cylinder.

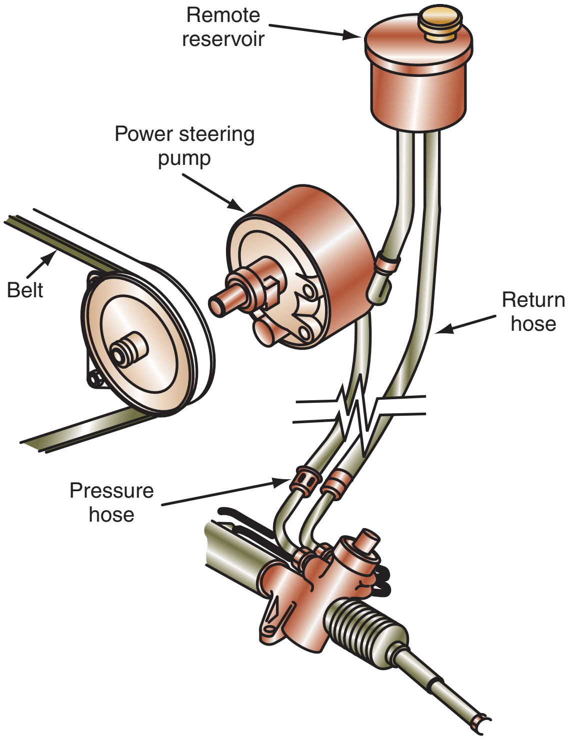

FIGURE 10-6 **Remote reservoir on power-assisted rack and pinion steering system.**

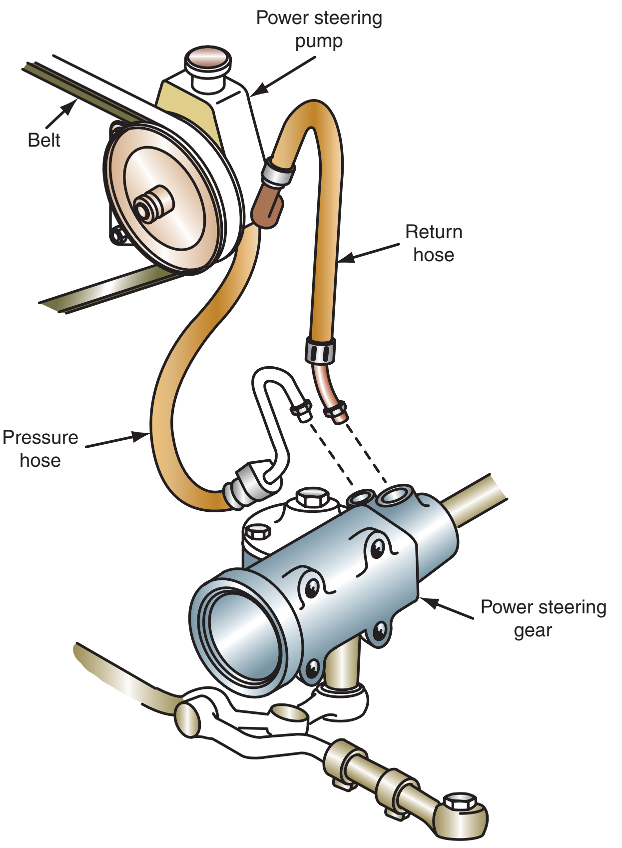

FIGURE 10-7 **Integral power-assisted steering system.**

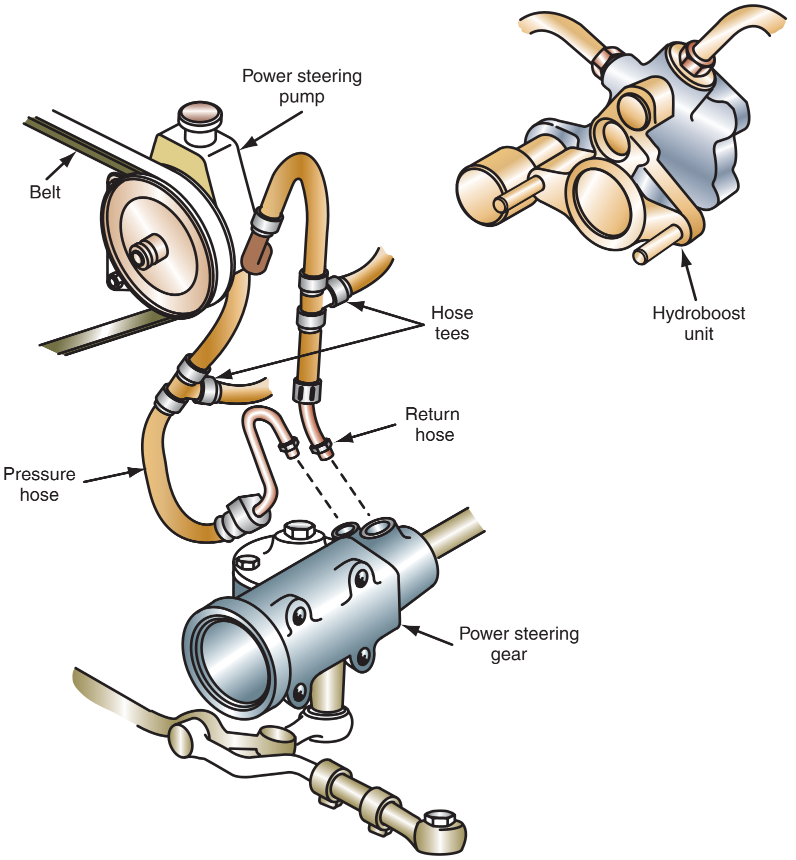

FIGURE 10-8 **Hydroboost power-assisted steering and brake system.**

Power Steering Pump Design

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Various types of power steering pumps have been used by car manufacturers. Many **vane-type power steering pumps** have flat vanes that seal the pump rotor to the elliptical pump cam ring (Figure 10-9). Other vane-type power steering pumps have rollers to seal the rotor to the cam ring. In some pumps, inverted, U-shaped slippers are used for this purpose. The major differences in these pumps are in the rotor design and the method used to seal the pump rotor in the elliptical pump ring. The operating principles of all three types of pumps are similar.

A balanced pulley is pressed on the steering pump drive shaft. This pulley and shaft are belt-driven by the engine. A spring-loaded lip seal at the front of the pump housing prevents fluid leaks between the pump shaft and the housing. The oblong pump reservoir is made from steel or plastic. A large O-ring seals the front of the reservoir to the pump housing (Figure 10-10).

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Smaller O-rings seal the bolt fittings on the back of the reservoir. The combination cap and dipstick keeps the fluid reserve in the pump and vents the reservoir to the atmosphere. Some power steering pumps have a variable assist steering actuator in the back of the pump housing. The PCM operates this actuator to provide increased steering assist at low vehicle speeds.

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The rotating components inside the pump housing include the shaft and rotor with the vanes mounted in the rotor slots. A seal between the output shaft and the housing prevents oil leaks around the shaft. As the pulley drives the pump shaft, the vanes rotate inside an elliptically shaped opening in the **cam ring**. The cam ring remains in a fixed position inside the pump housing. A pressure plate is installed in the housing behind the cam ring (Figure 10-11).

CAUTION:
Avoid prying on the power steering pump reservoir, because this action can damage or puncture the reservoir.

A spring is positioned between the pressure plate and the end cover, and a retaining ring holds the end cover in the pump housing. The flow control valve is mounted in the pump housing, and a magnet is positioned on the pump housing to pick up metal filings rather than allowing them to circulate through the power steering system (Figure 10-12).

The flow control valve is a precision-fit valve controlled by spring pressure and fluid pressure. Any dirt or roughness on the valve results in erratic pump pressure. The flow control valve contains a pressure relief ball (Figure 10-13). High-pressure fluid is forced past the control valve to the outlet fitting. A high-pressure hose connects the outlet fitting to the inlet fitting on the steering gear. A low-pressure hose returns the fluid from the steering gear to the inlet fitting in the pump reservoir.

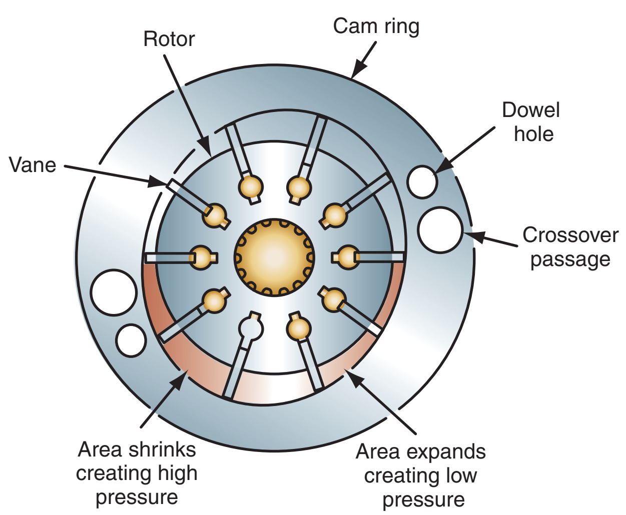

FIGURE 10-9 **Power steering pump rotor and vanes.**

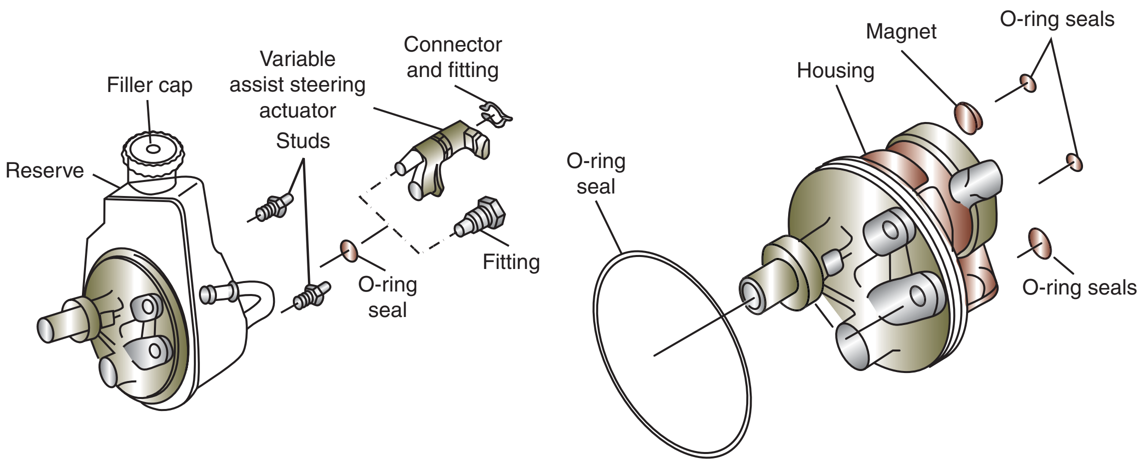

FIGURE 10-10 **Power steering pump housing and reservoir.**

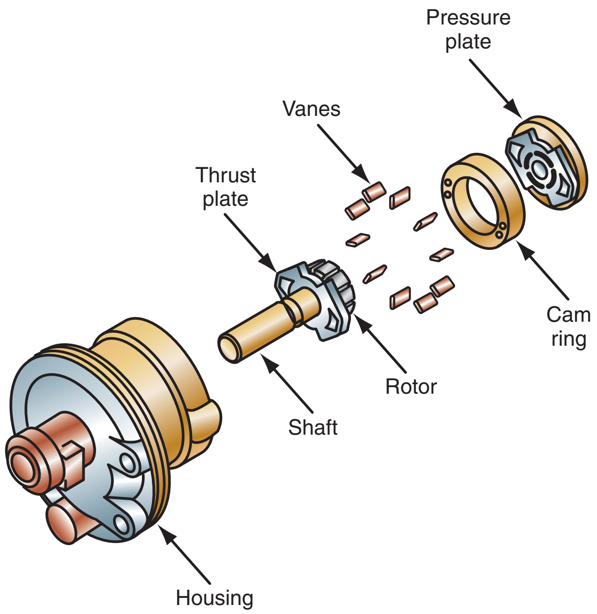

FIGURE 10-11 **Power steering pump housing with shaft and rotor, vanes, cam ring, and pressure plate.**

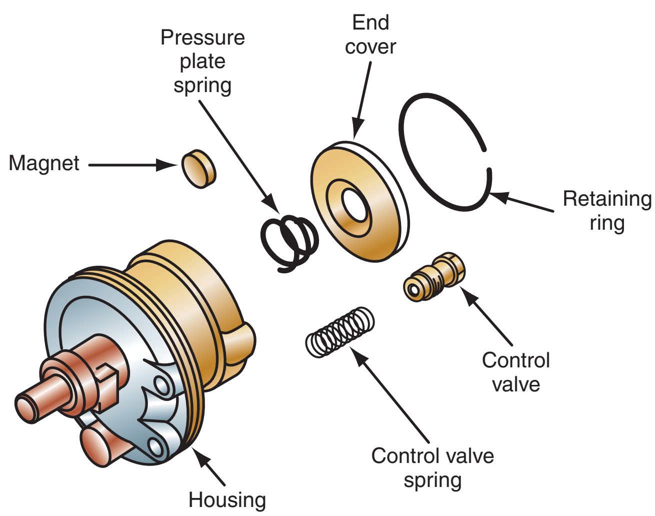

FIGURE 10-12 **Power steering pump housing assembly with end cover, flow control valve, and magnet.**

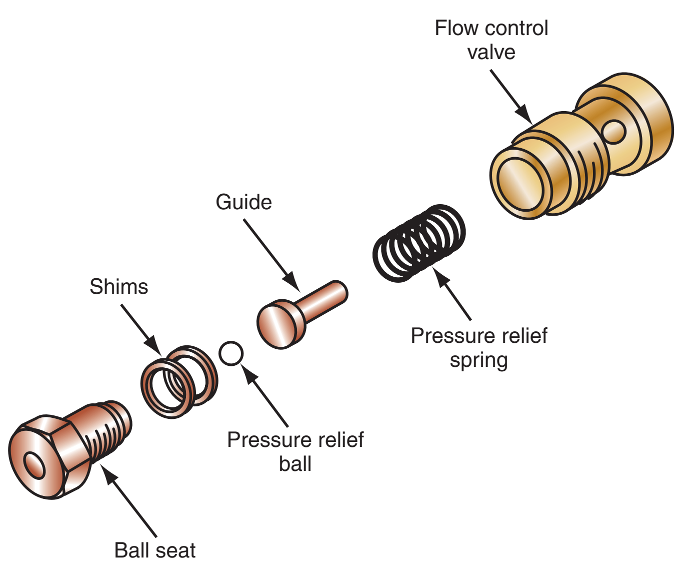

FIGURE 10-13 **Flow control valve.**

Power Steering Pump Operation

Vane and Cam Action

As the belt rotates the rotor and vanes inside the cam ring, centrifugal force causes the vanes to slide out of the rotor slots. The vanes follow the elliptical surface of the cam. When the area between the vanes expands, a low-pressure area occurs between the vanes and fluid flows from the reservoir into the space between the vanes. As the vanes approach the higher portion of the cam, the area between the vanes shrinks and the fluid is pressurized.

The **flow control valve** controls the fluid from the pump to the steering gear.

High-pressure fluid is forced into two passages on the thrust plate. These passages reverse the fluid direction. Fluid is discharged through the cam crossover passages and pressure plate openings to the high-pressure cavity and **flow control valve**. The fluid is discharged from the flow control valve through the outlet fitting (Figure 10-14). Though most of the fluid is discharged from the pump, some fluid returns to the bottom of the vanes past the flow control valve and through the bypass passage.

A **venturi** is a narrow area in a pipe through which a liquid or gas is flowing. When liquid or gas flow increases in the venturi, the pressure drops proportionally. If liquid or gas flow decreases, the pressure in the venturi increases.

A machined **venturi** orifice is located in the outlet fitting. Fluid passage applies pressure from the venturi area to the spring side of the flow control valve. When fluid flow in the venturi increases, the pressure in this area decreases.

Power Steering Pump Operation at Idle Speed

At idle speed with the wheels straight ahead, the flow of fluid from the pump to the steering gear is relatively low. Under this condition, the steering gear valve is positioned so the fluid discharged from the pump is directed through the valve and the low-pressure hose to the pump vane inlet. With low fluid flow, the pressure is higher in the venturi and control orifice. This higher pressure is applied to the spring side of the flow control valve and helps the valve spring keep this flow control valve closed (Figure 10-15). Under this condition, pump pressure remains low, and all the fluid is discharged from the pump through the steering gear valve and back to the pump inlet.

Power Steering Pump Operation at Higher Engine Speeds

The **outlet fitting venturi** controls the pressure supplied to the flow control valve.

When engine speed is increased, the power steering pump delivers more fluid than the system requires. This increase in fluid flow creates a pressure decrease in the **outlet fitting venturi**. This pressure reduction is sensed at the spring side of the flow control valve, which allows the pump discharge pressure to force the flow control valve partially open. Under this condition, the excess fluid from the pump is routed past the flow control valve to the pump inlet. If the steering wheel is turned, the fluid discharged from the pump rushes into the pressure chamber in the steering gear.

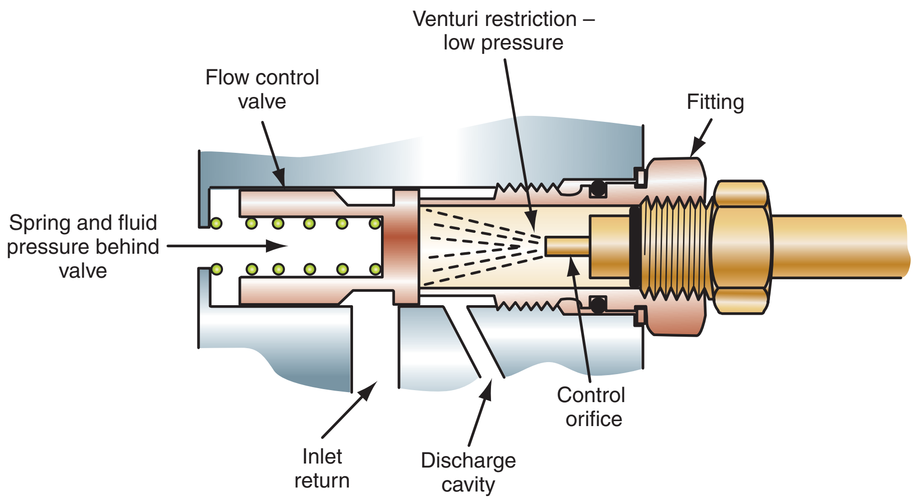

FIGURE 10-14 **Power steering pump fluid flow to control valve and outlet fitting.**

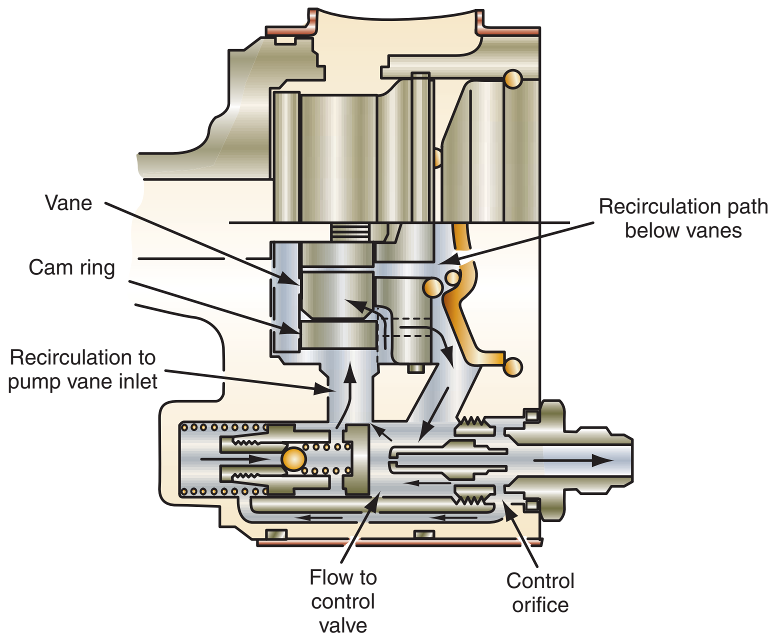

FIGURE 10-15 **Flow control valve operation under various conditions.**

Power Steering Pump Operation During Pressure Relief

If the steering wheel is turned fully in either direction until the steering linkage contacts the steering stops, the rack piston is stopped. Under this condition, pump pressure could become extremely high and damage hoses or other components. When the rack piston stops, the flow from the pump decreases, but the high pump pressure is still directed through the steering gear valve to the rack piston. Since the flow of fluid through the venturi and control orifice is reduced, a higher pressure is present in this area. This extremely high pressure is also supplied to the spring end of the flow control valve. At a predetermined pressure, the **pressure relief ball** in the center of the flow control valve is unseated and the flow control valve moves to the wide-open position. This action allows some of the high pressure in the steering system to return to the pump inlet, which limits pump pressure to a maximum safe value.

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The **pressure relief ball** limits the maximum power steering pump pressure.

Hybrid Vehicles and Power Steering Systems

Advantages and Types of Hybrid Electric Vehicles

Hybrid electric vehicles (HEVs) have two power sources, typically a small displacement gasoline engine and a high-voltage battery pack that supplies voltage and current to an electric drive motor(s).

The two most common types of hybrid vehicles are **series HEVs** and **parallel HEVs**. In a series HEV powertrain, the mechanical power from engine is combined with electric power from the generator and/or battery pack to drive the vehicle (Figure 10-16). In a parallel HEV powertrain, the mechanical power from the engine or electric power from the generator and/or battery pack may be delivered separately to the drive wheels or the power from both of these sources may be combined and delivered to the drive wheels (Figure 10-17). In a parallel HEV, electric power alone may be supplied to the drive wheels to drive the vehicle, whereas in a series HEV, electric power only cannot drive the vehicle.

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In a **series HEV**, electric power from the battery pack and/or generator and mechanical power from the engine are supplied together to the drive wheels.

The advantages of an HEV are increased fuel economy and reduced emissions. It is extremely important that all other systems and vehicle design are engineered to help achieve these objectives. Many HEVs have a smaller displacement engine compared with an equivalent-size non-hybrid vehicle. In a typical HEV, the smaller displacement engine coupled with the electric propulsion motor provides equivalent, or nearly equivalent, power compared

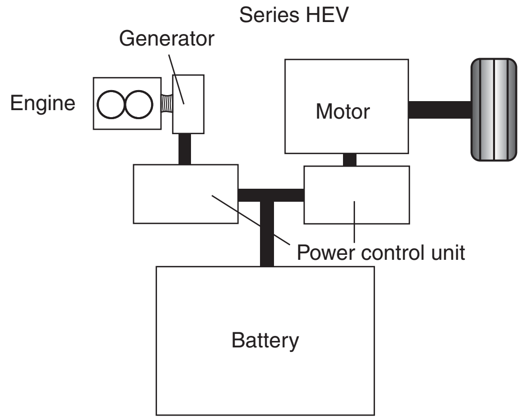


FIGURE 10-16 **Series HEV.**

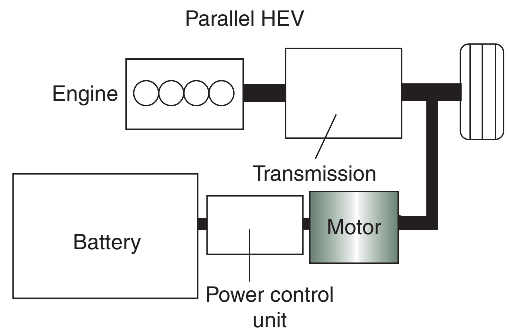


FIGURE 10-17 **Parallel HEV.**

In a **parallel HEV,** electric power from the battery pack and/or generator and mechanical power from the engine may be supplied separately to the drive wheels or these two power sources may be combined.

with that provided in a non-hybrid vehicle. The smaller displacement engine in the HEV supplies improved fuel economy compared with that provided by the larger engine in the non-hybrid vehicle. Improved fuel economy is also achieved because the electric propulsion motor supplies some of the power to the drive wheels. In many HEVs, under specific operating conditions, the engine is shut off and power is supplied to the drive wheels only by the electric motor to provide an additional fuel saving.

On many HEVs, the engine is stopped to conserve fuel and reduce emissions when the vehicle is standing still and the engine is warmed up and idling. Under this condition, the power steering must be active and ready to provide power steering assist if the driver turns the steering wheel. To meet this requirement, electrohydraulic power steering pumps are presently installed on some HEVs.

Hybrid Powertrain Components

Engine to Transaxle Coupling

In some HEVs, the engine and propulsion motors are coupled through a torque splitting planetary gear set to an electronically controlled continuously variable transaxle (CVT). The engine is coupled to the carrier in the planetary gear set (Figure 10-18). The propulsion motor is connected to the planetary ring gear, and the generator is attached to the planetary sun gear. The drive gear that transfers torque to the transaxle is attached to the electric motor drive shaft. This arrangement allows torque from the engine, the propulsion motor, or both the engine and propulsion motor to be transferred to the transaxle and drive wheels. The sun gear is the smallest gear in the planetary gear set.

Propulsion Motor/Generator

Regenerative braking occurs during vehicle deceleration when the drive motor becomes a generator and supplies current to recharge the batteries.

The propulsion motor is an AC synchronous permanent magnet, liquid-cooled type. Some propulsion motors are rated at 40 hp (30 kW) at 940 to 2000 rpm and 225 ft-lb (305 Nm) peak torque at 0 to 940 rpm. During deceleration and braking, the propulsion motor acts as a generator to recharge the batteries. This action is called **regenerative braking.** In Figure 10-19, the propulsion motor is identified as MG2 and the generator is identified as MG1. Some propulsion motors have higher torque and horsepower output depending on the motor design. Later model propulsion motors are capable of turning at speeds in excess if 12,000 rpm.

Generator/Starter

The generator is an AC synchronous type that produces voltage and current to recharge the batteries and power the electrical system. When starting the engine, current is supplied through the generator stator windings, and the generator cranks the engine. Under

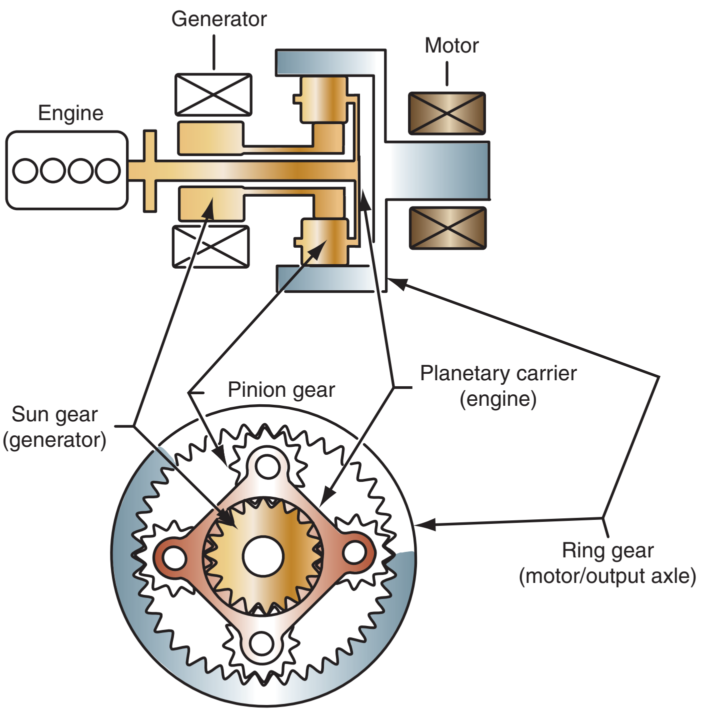


FIGURE 10-18 **Planetary gear coupling between engine, electric motor, and transaxle.**

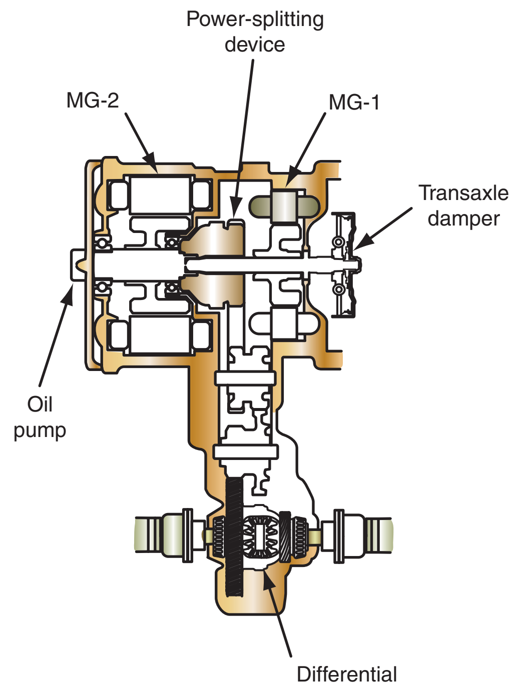


FIGURE 10-19 **Electric drive motor (MG-2) and generator (MG-1).**

normal driving conditions, current from the generator is routed to the electric drive motor to increase the torque supplied to the drive wheels. In later model HEVs, generator design has been improved to allow higher generator rpm and improved generator output. In some current HEVs, the generator is capable of turning at 10,000 rpm, whereas some early model generators turned at 6,500 rpm.

Inverter

The inverter contains the power control unit that controls the voltage and current supplied by the batteries to the propulsion motor. The battery pack supplies high DC voltage to the inverter and the inverter converts the DC voltage to 3-phase AC voltage that is supplied to the propulsion motor. The inverter also controls the voltage and current supplied from the propulsion motor to the batteries during regenerative braking. Because the voltage and current supplied from the batteries to the propulsion motor may be very high, the inverter contains insulated gate bipolar transistors (IGBT) to control this circuit (Figure 10-20). This high voltage and current controlled by the inverter produces a considerable amount of heat, and the inverter is cooled by a dedicated cooling system to dissipate this heat. Heavy cables are connected between the batteries, inverter, and the propulsion motor. For easy identification, these cables and connectors have orange insulation.

WARNING: The high voltage in circuit between the batteries, inverter, and propulsion motor could electrocute a technician. It is very important to follow the vehicle manufacturer's recommended procedures when diagnosing and servicing HEVs.

WARNING: Never touch, cut, pierce, or open any orange high voltage cable, or high voltage component. This action may cause severe electrical shock or electrocution.

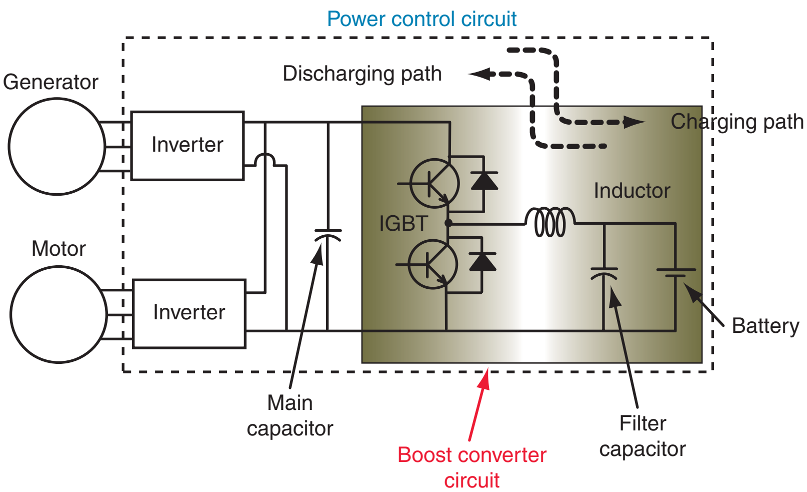


FIGURE 10-20 **High voltage power circuit in the inverter.**

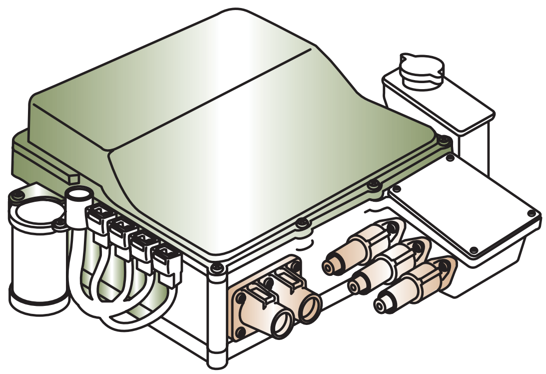


FIGURE 10-21 **Inverter.**

The AC voltage and current supplied from the generator to the 12V battery and electrical accessories is converted to DC voltage by the inverter and controlled in 14V–15V range. The inverter is illustrated with the cover removed in Figure 10-21.

Battery Pack and Related Cables

Some battery packs contain 240 cylindrical nickel-metal-hydride cells connected in series. Each cell has 1.2V for a total of 288V. Some HEVs have a higher voltage depending on the number of cells in the battery. The battery cells are connected in groups, with 6 cells in each group. The battery pack is installed behind the rear seat in some HEVs. The electrolyte is a gel in the nickel-metal-hydride battery pack, and so leakage is not a great concern. A cooling fan helps cool the battery pack. In the unlikely case of battery overcharging, a battery pack vent hose allows vapors from the battery pack to be vented outside the vehicle trunk.

Many battery packs have a long warranty period such as 10 year, 90,000 mi. (150,000 km). Positive and negative high voltage cables are connected between the battery pack and the inverter. These cables are routed under the vehicle floor pan and they are completely insulated from the chassis to avoid any possibility of electrical shock when touching the chassis.

HEV components increase vehicle weight, which reduces vehicle performance and increases fuel consumption. Therefore, it is very important to reduce the weight of HEV components and also design other vehicle components with less weight.

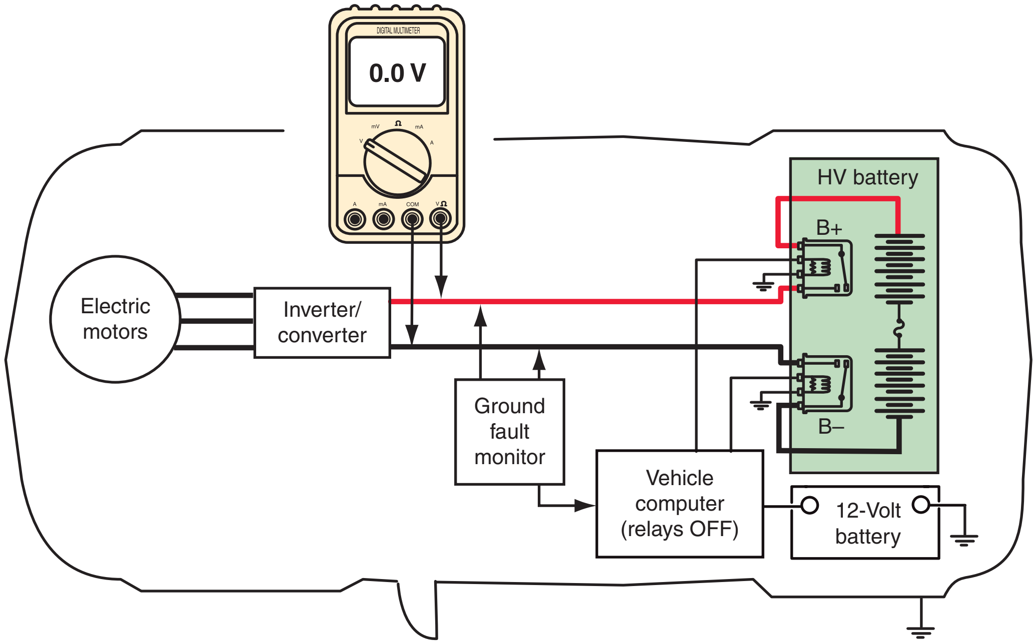
Some HEVs are currently equipped with lithium-ion batteries, which are 40% lighter and take up 24% less space compared with a nickel-metal-hydride battery with the same power output.

AUTHOR'S NOTE: One of the major Japanese vehicle manufacturers has just introduced a lithium-ion battery with a new internal design that has only one-half the volume but 1.5 times the power output compared with previous lithium-ion batteries.

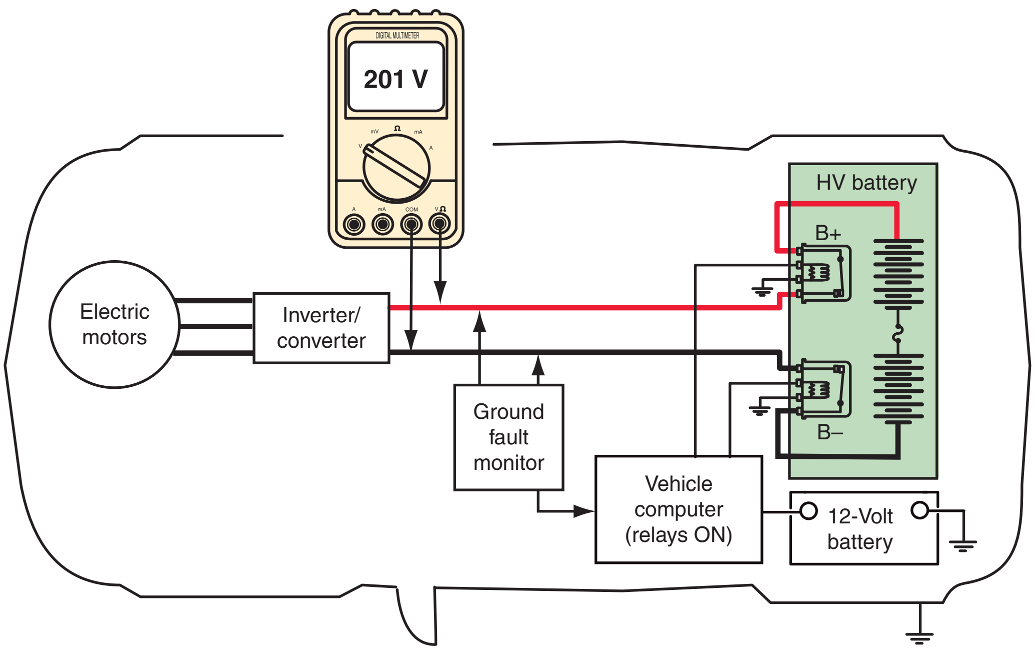
HEV Indicators

Some HEVs have normally open battery-pack relays that open and close the circuit between the battery pack and the inverter. The vehicle computer controls these relays.

A READY indicator in the dash informs the driver when the relays are closed and the batteries are connected to the inverter. When the ignition switch is off, the relays in the high voltage circuit are open and the READY indicator is off. If the ignition switch is on and the relays are closed, voltage is supplied from the battery pack to the inverter, and the READY



High Voltage System – Vehicle Shut Off (READY -off)



High Voltage System – Vehicle On and Operational (READY -on)

FIGURE 10-22 **High voltage electrical system.**

indicator is illuminated (Figure 10-22). The engine may stop and start any time while the READY indicator is illuminated. Never assume the electrical system is off just because the engine is stopped. The electrical system is off when the READY indicator is off. If the vehicle is involved in a collision, and the air bags are deployed, the battery pack relays automatically open and disconnect the voltage supplied from the battery pack to the inverter. When the engine is running, a ground fault monitor continuously monitors the high voltage system for high voltage leakage to the metal chassis. If leakage occurs, the vehicle computer illuminates the master warning light in the instrument cluster (Figure 10-23) and the hybrid warning

FIGURE 10-23 **Master warning light.**

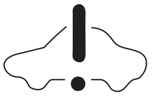


FIGURE 10-24 **Hybrid warning light.**

light in the liquid crystal display (LCD) (Figure 10-24). The conventional 12V lead acid battery is located in the truck near the battery pack. The positive cable from the 12V battery is routed to the engine compartment with the high voltage cables from the battery pack. HEV systems and indicators vary depending on the vehicle make and model year.

HEV Operation

When the engine is at normal operating temperature, and the vehicle is starting off from a stop or operating at very low speed and light load, only electrical power from the battery pack is supplied to the propulsion motor to drive the vehicle (Figure 10-25).

During normal driving, mechanical power from the engine and electric power supplied from the generator to the propulsion motor are used to drive the vehicle (Figure 10-26).

If the engine is operating at wide throttle opening, mechanical power from the engine and electric power from the generator and battery pack are supplied to drive the vehicle (Figure 10-27).

During vehicle deceleration, the propulsion motor acts as a generator and supplies current to charge the batteries (Figure 10-28).

If the battery state of charge becomes low, more of the electric power from the generator is transmitted to the battery pack for recharging (Figure 10-29).

Power Steering and Hybrid Vehicles

Many HEVs have a stop/start function that allows the engine to be shut off when the vehicle has come to a complete stop, with the engine idling. When the ignition switch is on and the driver steps on the accelerator pedal, the vehicle starts off, and the engine may restart at any time depending on throttle opening and other factors. The power steering must be operational even during the engine stop part of the stop/start function. To maintain power steering operation during the stop function, some vehicle manufacturers use an electronic power steering (EPS) gear. Some of these EPSs have an electric motor driving the steering gear pinion (Figure 10-30). A power steering control module supplies current to the EPS motor to supply the proper amount of steering assist. The EPS is fully operational when the ignition switch is turned on.

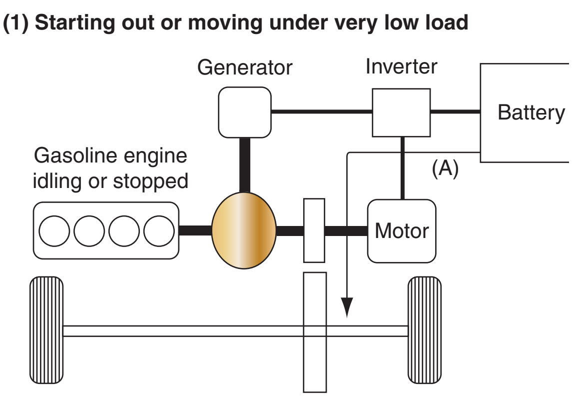


FIGURE 10-25 **HEV starting off or operating at low speed and light load.**

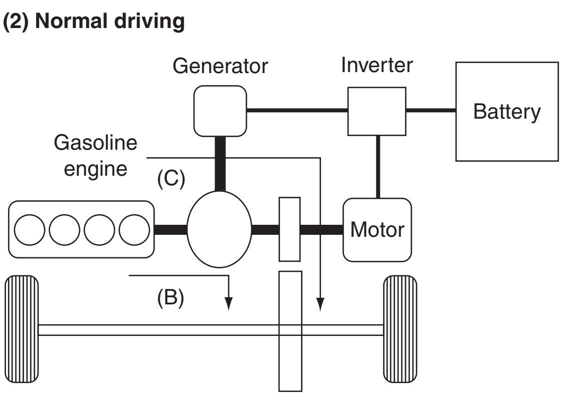


FIGURE 10-26 **HEV operation during normal driving.**

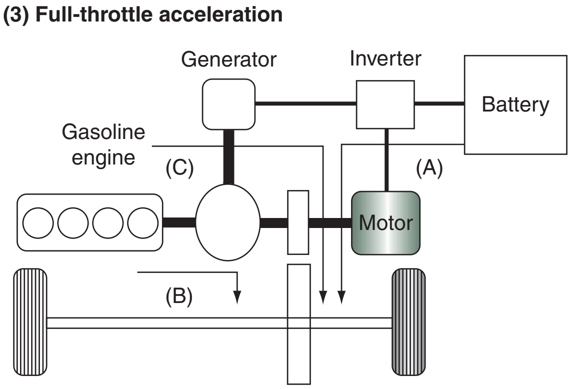


FIGURE 10-27 **HEV operation at wide open throttle.**

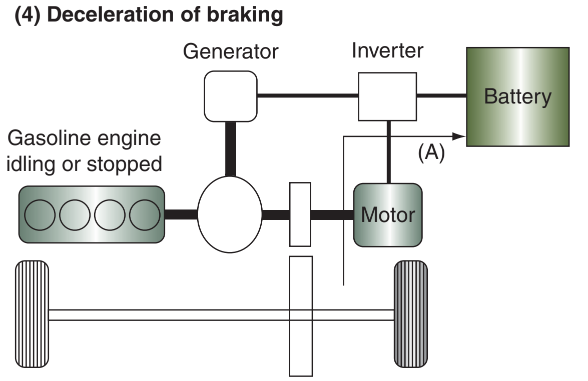


FIGURE 10-28 **HEV operation during deceleration.**

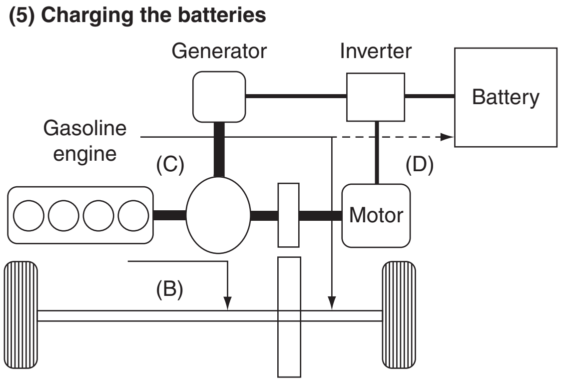


FIGURE 10-29 **HEV operation with low battery state of charge.**

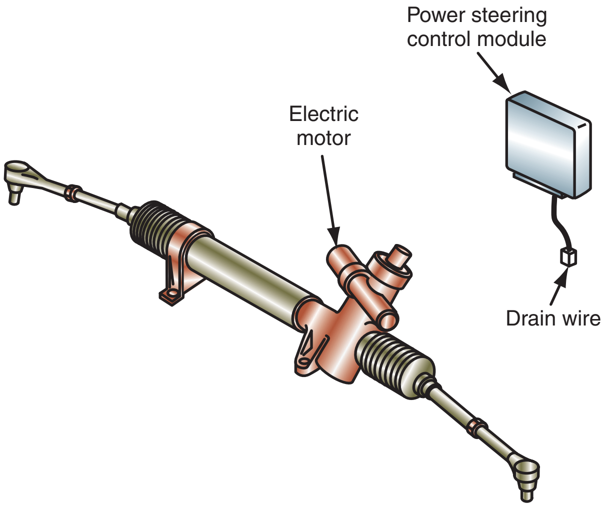


FIGURE 10-30 **Electronic power steering (EPS).**

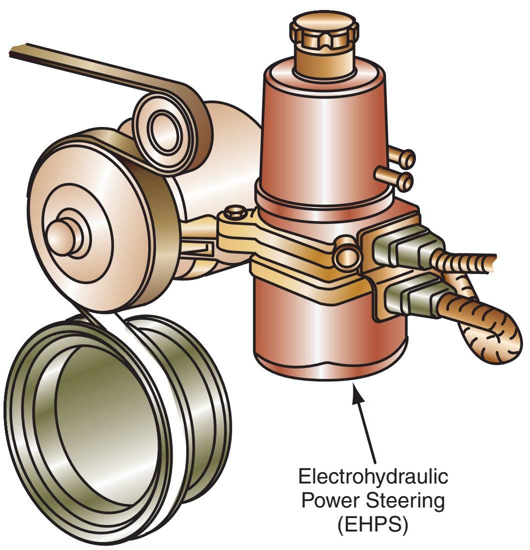


FIGURE 10-31 **Electrohydraulic power steering (EHPS) module.**

Other HEVs have an electrohydraulic power steering pump to maintain power steering pump operation during the stop function. This type of pump has an electric motor driving the pump rather than a belt drive (Figure 10-31). The electrohydraulic power steering pump contains the pump and electric drive motor, reservoir with filler cap, and the control module. Voltage signals are sent from the steering wheel position sensor in the steering column and the brake pedal position sensor actuated by the brake pedal to the control module.

In response to these signals, the control module determines the amount of power steering assist required. In some electrohydraulic power steering pumps, 42 V are supplied from the inverter in the HEV to the power steering pump.

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When a higher voltage is supplied to the power steering pump motor, less current is required to drive the motor. For example, electrical energy is measured in watts (W) and watts are calculated by multiplying the amperes by the volts. When 12 V are supplied to a headlight, 3 amperes may be required to illuminate the light. The electrical energy required to illuminate the light is $12 \times 3 = 36$ W. If 18 V are supplied to the headlight, only 2 amperes are required to illuminate the light. The advantage of increasing the voltage is that the same watts can be obtained with less amperes.

AUTHOR'S NOTE: One leading manufacturer's worldwide sales of HEVs surpassed 1.5 million units in 2008. The average silicon content on a non-hybrid vehicle consumes approximately 30 percent of an 8 in. (3.1 cm) silicon wafer. The silicon content of a hybrid vehicle requires the full 8 in. (3.1 cm) wafer. Approximately, 50 percent of the cost of a hybrid vehicle is in the hardware and software. Toyota has taken 70 percent of the cost of the hybrid technology out of the hybrid Prius, improved its fuel economy, and increased the size of the chassis/body.

Various Types of HEVs

Belt-Driven HEVs

Some HEVs have a belt-driven motor/generator with an improved drive belt and tensioner compared with a conventional generator (Figure 10-32). The latest belt-driven HEV system features a stop/start function, regenerative braking, intelligent battery charging, and 4 kW of energy are supplied from the battery pack to the motor/generator for up to 5 seconds during wide throttle, heavy load driving. Some belt-driven HEVs supply a modest electric-only propulsion below 8 mph (8 km/h). Lithium-ion batteries will soon be available in some belt-driven HEV systems.

Plug-in HEVs

Several major vehicle manufacturers are scheduled to introduce plug-in HEVs (PHEVs) in their showrooms during 2010. A PHEV may be driven only by an electric motor(s), but a small gasoline or diesel engine is installed in the vehicle for extra power or to drive a generator and recharge the batteries. A typical PHEV may be driven for 40 mi. (64 km) using only electric power. When the batteries reach a specific state of discharge, the engine starts and drives the generator to recharge the batteries.

FIGURE 10-32 **Belt-driven hybrid system components.**

Extended Range Electric Vehicle

An extended range electric vehicle (EREV) is similar to a PHEV. The EREV has a small gasoline or diesel engine that drives a generator to recharge the batteries. The engine only drives the generator; it cannot supply power to the drive wheels. The Chevrolet Volt is an EREV.

Fuel Cell Vehicles

Fuel cell vehicles (FCVs) are not presently available in the automotive showrooms. However, many car manufacturers around the world are working on this technology. Several vehicle manufacturers have designed and produced FCVs, and a significant number of these vehicles have been released to various fleet owners and officials to gain field experience and determine how these vehicles perform in the real world.

An FCV has an electric-drive motor(s), and the fuel cell supplies electricity to this drive motor(s). The fuel cell must be supplied with hydrogen as a fuel, and the fuel cell produces electricity as the hydrogen and air flow through the cell. There are various types of fuel cells, but the most common type is the proton exchange membrane (PEM) fuel cell. The fuel cell actually contains a large group of cells. The only by-product from fuel cell operation is water vapor. A PEM fuel cell is compared to an internal combustion engine in Figure 10-33. The FCV requires a source of high voltage and current such as a battery pack and/or ultra-capacitor to supply extra current to the drive motor during operation at wide throttle openings. The disadvantages of FCVs are these:

1. The size, weight, and cost of the FCV components. Fuel cells are very expensive at present.
2. The lack and cost of hydrogen refueling facilities.
3. The cost and availability of FCVs.
4. Difficulty in storing hydrogen onboard vehicles; liquid hydrogen must be stored under pressure in special insulated tanks. It is difficult to store a sufficient amount of gaseous hydrogen onboard a vehicle.

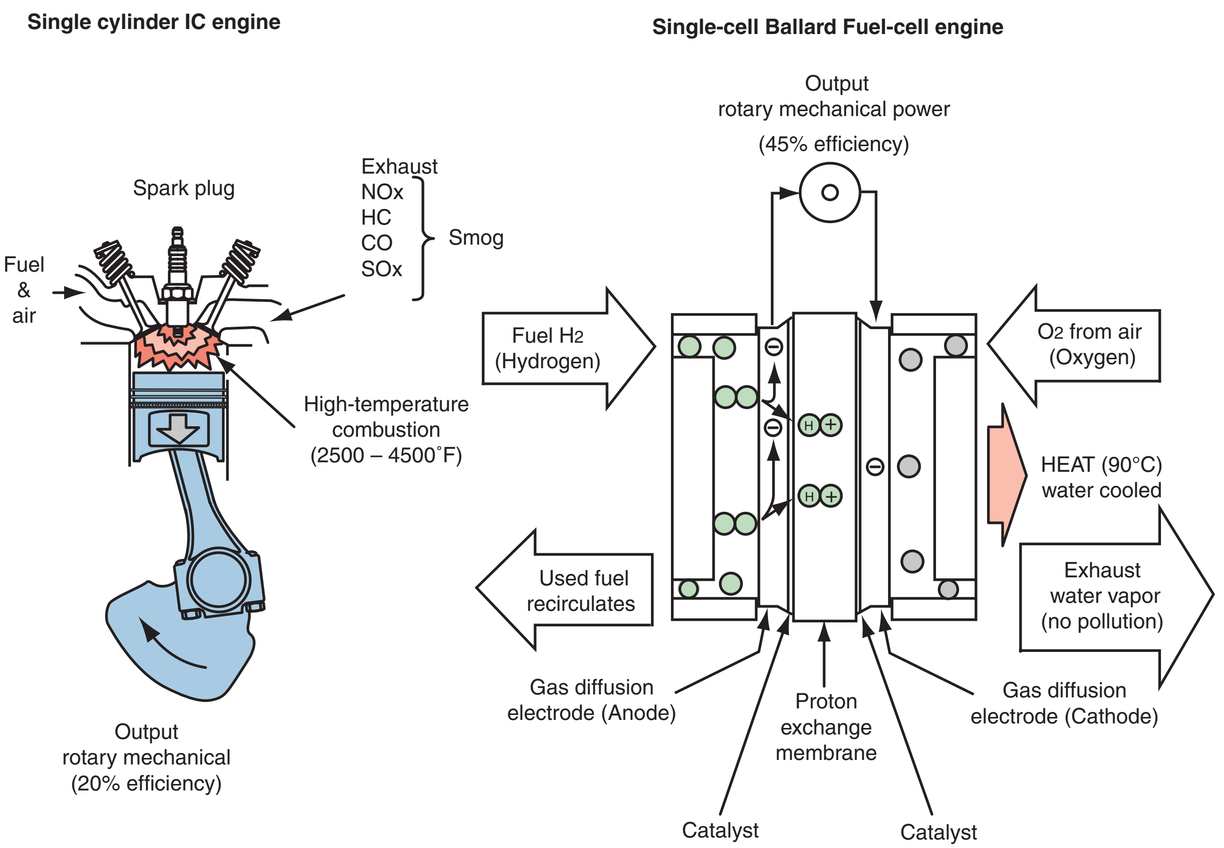


FIGURE 10-33 **Comparison between an internal combustion engine and a fuel cell.**

The advantages of FCVs are:

1. Reduced dependency on high-priced hydrocarbon fuels.
2. Hydrogen may be obtained from several different sources.
3. Greatly reduced tailpipe and evaporative emissions.

AUTHOR'S NOTE: The Chairman of the Board of Management for one of the major European vehicle manufacturers recently stated, "We are convinced that by 2014–2015 we can offer technically and economically competitive fuel cell vehicles in the range of 100,000 plus units per year. We are very, very serious about fuel cells. We will have mass-produced vehicles without emissions in the timeframe I have outlined. We have to."

SUMMARY

- A serpentine belt or a conventional V-belt may be used to drive the power steering pump.
- The friction surfaces are on the sides of a V-belt.
- A serpentine belt may be used to drive all the belt-driven components. This allows these components to be on the same vertical plane.
- Proper belt tension is extremely important for adequate power steering pump operation.
- A rack and pinion steering gear is usually mounted on the cowl or the front crossmember.
- Rack and pinion steering gears are used in many front-wheel-drive cars.
- Integral power steering gears are usually mounted on the vehicle frame.
- Integral power steering systems are found on many rear-wheel-drive cars and light-duty trucks.
- A power steering pump may have an integral or a remote fluid reservoir.
- In a hydroboost power-assisted steering system, fluid pressure from the power steering pump is applied to the steering gear and the brake master cylinder. The power steering pump pressure acts as a booster to assist the driver in applying the brakes.
- A power steering pump may have a vane, roller, or slipper-type rotor assembly, but all three types of pumps operate on the same basic principle.
- The flow control valve in a power steering pump is moved toward the closed position by spring pressure and fluid pressure from the venturi in the pump outlet fitting.
- When a vehicle is driven at low speeds with the front wheels straight ahead, the power steering pump fluid flow is lower. Under this condition, the pressure in the outlet fitting venturi is higher. This higher pressure together with the spring tension keeps the flow control valve closed. In this valve position, a small amount of fluid is routed past the flow control valve to the pump inlet.
- If engine speed is increased, the pump delivers more fluid than the system requires. This increase in pump flow reduces pressure in the outlet fitting venturi. This pressure decrease is applied to the spring side of the flow control valve. This action allows the flow control valve to move toward the partially open position, and excessive pump flow is returned past the flow control valve to the pump inlet.
- If the driver turns the steering wheel, fluid rushes from the pump outlet into the steering gear pressure chamber. Under this condition, the flow control valve moves toward the closed position to maintain pump pressure and flow to the steering gear.
- If the front wheels are turned all the way against the stops, the power steering pump pressure could become high enough to damage hoses or other components. Under this condition, the high pump pressure unseats a pressure relief ball in the center of the flow control valve. This action allows some pump flow to move past the pressure relief ball to the pump inlet, which limits pump pressure.
- Most HEVs are powered by a small gasoline engine and a battery pack, generator, and electric motor.

TERMS TO KNOW

Brake-by-wire
Cam ring
Energy storage box
Flow control valve
Hybrid vehicles
Hydroboost power-assisted steering system
Integral power-assisted steering system
Integral reservoir
Outlet fitting venturi
Parallel HEVs
Pressure relief ball
Rack and pinion power steering system

SUMMARY

- In a series HEV, mechanical power from the engine is combined with electric power from the battery pack and generator and supplied to the drive wheels.
- In a parallel HEV, electric power only from the battery pack and generator may be supplied to the drive wheels or a combination of electric power and engine power may be sent to the drive wheels.
- The stop/start function in an HEV allows the engine to stop when the vehicle is not moving and the engine is at normal temperature and idling. When the driver steps on the accelerator pedal, vehicle operation is immediately restored.
- A belt-driven HEV system has a belt-driven motor/generator and provides a stop/start function, regenerative braking, and electric power boost to the drive wheels.
- In a PHEV, electric power only is supplied to the drive wheels, and a small gasoline or diesel engine drives a generator to recharge the battery pack.
- An FCV has only electric power supplied to the drive wheels. A fuel cell and battery pack supply the electricity to drive the vehicle, and hydrogen and air are supplied to the fuel cell to create the electricity.

TERMS TO KNOW

(continued)

Regenerative braking
Remote reservoir
Series HEVs
Serpentine belt
Steer-by-wire
Vane-type power steering pumps
V-belt
Venturi
Serpentine belt

REVIEW QUESTIONS

Short Answer Essays

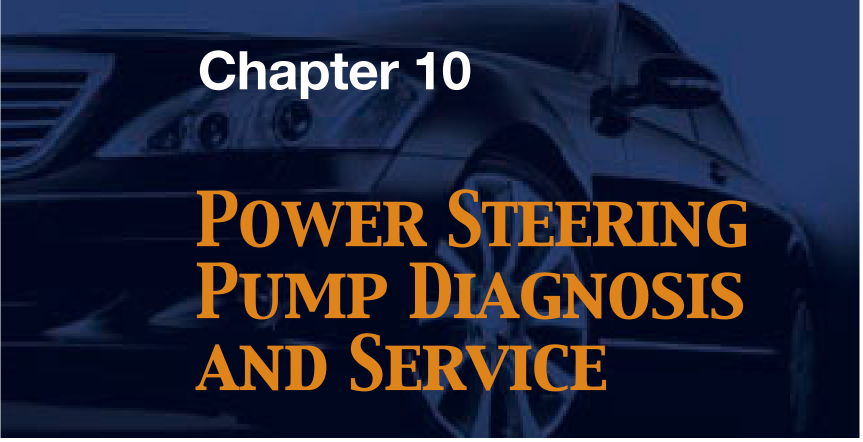
1. Describe the proper position of a V-belt in a pulley.
2. Explain two advantages of a serpentine belt compared with a conventional V-belt.
3. List two possible locations for mounting a rack and pinion steering gear.
4. List the most common applications for rack and pinion and integral steering gears.
5. Describe how the brake boost pressure is obtained in a hydroboost power steering system.
6. Explain how the fluid pressure is produced in a vane-type power steering pump.
7. List the forces that move the flow control valve toward the closed position in a power steering pump.
8. Describe the operation of a venturi.
9. Explain the operation of the flow control valve when the steering wheel is turned.
10. Describe the operation of the power steering pump when the steering wheel is rotated all the way to the right or left until the front wheels contact the stops.

Fill-in-the-Blanks

1. The lower edge of a V-belt should never contact the _______________ _______________.
2. Excessive belt wear occurs if pulleys are _______________.
3. Many serpentine belts have a spring-loaded _______________.
4. The master cylinder in a hydroboost system does not have a conventional _______________ _______________.
5. The purpose of the vanes in the power steering pump rotor is to _______________ the rotor in the elliptical cam ring.
6. As the power steering pump shaft and rotor turn, _______________ _______________ causes the vanes to move outward against the cam ring.
7. A machined venturi is located in the power steering pump _______________ _______________.
8. When fluid movement through the venturi increases, the pressure in the venturi _______________.
9. With the engine running and the front wheels straight ahead, the power steering pump pressure is _______________.
10. The pressure relief ball in a power steering pump is forced open when the front wheels are turned against the _______________.

Multiple Choice

1. The most likely result of a power steering V-belt that is bottomed in the pulley is:
   A. Belt slipping.
   B. Belt breaking.
   C. Belt contamination.
   D. Wear on the power steering pump pulley.
2. All of these statements about a serpentine belt are true EXCEPT:
   A. A serpentine belt can be used to drive all the belt-driven components.
   B. The back side or a serpentine belt can drive one component.
   C. A serpentine belt is narrower than a conventional V-belt.
   D. A serpentine belt can have an automatic belt tensioner.
3. A hydroboost power steering system:
   A. Is used on many small front-wheel-drive vehicles.
   B. Uses pressure from the power steering pump to provide brake boost.
   C. Has a conventional vacuum brake booster.
   D. Has a very high capacity power steering pump.
4. In an HEV, regenerative braking occurs during:
   A. Wide open throttle operation.
   B. Normal cruising speed.
   C. Low speed acceleration.
   D. Deceleration.
5. All of these statements about integral-type power steering pump sealing are true EXCEPT:
   A. A large O-ring seal is positioned between the reservoir and the pump housing.
   B. A lip seal on the pump drive shaft prevents oil leaks around the shaft.
   C. Lip seals are mounted on bolt fittings on the back of the reservoir.
   D. The cap and dipstick provide a seal on the top of the reservoir neck.
6. A power steering system experiences repeated belt failures with normal power steering system operation. The most likely cause of this problem is:
   A. A misaligned power steering pump pulley.
   B. A loose power steering pump belt.
   C. Low fluid level in the power steering reservoir.
   D. A worn cam ring in the power steering pump.
7. During normal power steering pump operation:
   A. The flow control valve spring moves this valve toward the open position.
   B. The fluid pressure from the outlet fitting venturi moves the flow control valve toward the open position.
   C. Pump flow increases as the engine speed increases.
   D. The pressure relief valve opens when the engine speed is increased with the front wheels straight ahead.
8. All of these statements about power steering pump design and operation are true EXCEPT:
   A. An increase in fluid movement through the outlet fitting venturi causes a pressure decrease in the venturi.
   B. An increase in the flow control valve opening allows more fluid to return to the pump inlet.
   C. The rotor is attached to the pump shaft and must rotate with this shaft.
   D. Fluid pressure from the pump vanes moves the flow control valve toward the closed position.
9. All of these statements about an HEV are true EXCEPT:
   A. An inverter changes high AC voltage from the generator to a lower DC voltage for the 12 battery and vehicle accessories.
   B. In a series HEV, electric power only may be supplied to the propulsion motor.
   C. The inverter has a special cooling system.
   D. When the stop/start function is in operation, vehicle operation is restored when the driver steps on the accelerator pedal.
10. A vehicle experiences repeated ruptures of the high-pressure power steering hose. The most likely cause of this problem is:
    A. A pressure relief ball sticking closed.
    B. A flow control valve sticking open.
    C. Worn pump vanes and cam ring.
    D. A partially restricted power steering return hose.



Chapter 10

Power Steering Pump Diagnosis and Service

Upon completion and review of this chapter, you should be able to:

- Check power steering belt condition and adjust belt tension.
- Diagnose power steering belt problems.
- Check power steering fluid level and add fluid as required.
- Drain and flush power steering system.
- Bleed air from power steering system.
- Perform power steering pump pressure test.
- Check power steering pump fluid leaks.
- Remove and replace power steering pumps, and inspect pump mounts.
- Remove and replace power steering pump pulleys.
- Remove and replace power steering pump integral reservoirs.
- Remove, replace, and check flow control valve and pressure relief valve.
- Remove, replace, and check power steering pump rotating components.
- Remove and replace power steering pump seals and O-rings.
- Check, remove, and replace power steering lines.
- Inspect, test, diagnose, and service hybrid electric vehicles (HEVs) and electrohydraulic power steering (EHPS) systems.

BASIC TOOLS

Basic technician's tool set

Service manual

Pry bar

Floor jack

Safety stands

Oil drain pan

Crocus cloth

Power steering pump diagnosis and service is very important to maintain vehicle safety and driver convenience. If a badly worn power steering pump belt is undetected, the belt may suddenly break while the driver is completing a turn. Under this condition, steering effort is greatly increased, and this may result in a collision. Therefore, the power steering belt should be inspected at regular intervals. A loose power steering belt may cause hard steering intermittently, and this condition requires increased driver steering effort, which reduces driver comfort and convenience. Therefore, one of the first checks when diagnosing a power steering system is to inspect the belt condition and test the belt tension.

Power Steering Pump Belt Service

Checking Belt Condition and Tension

Power steering belt condition and tension are extremely important for satisfactory power steering pump operation. A loose belt causes low pump pressure and hard steering. The steering wheel may jerk and surge during a turn if the power steering pump belt is loose. A loose, dry, or worn belt may cause squealing and chirping noises, especially during engine acceleration and cornering.

SPECIAL TOOLS

Belt tension gauge

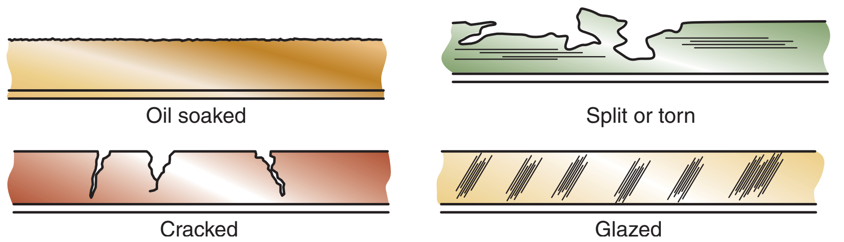


FIGURE 10-1 **Defective belt conditions.**

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CAUTION:
Do not pry on the pump reservoir with a pry bar. This action may damage the reservoir.

SERVICE TIP:
During rainy or wet conditions, a loose power steering belt, which causes low power steering pump pressure and increased steering effort, may be more noticeable because the belt becomes wet and slips more easily.

The power steering pump belt should be checked for tension, cracks, oil-soaking, worn or glazed edges, tears, and splits (Figure 10-1). If any of these conditions are present, belt replacement is necessary.

Since the friction surfaces are on the sides of a **V-type belt**, wear occurs in this area. If the belt edges are worn, the belt may be rubbing on the bottom of the pulley. This condition requires belt replacement. Belt tension may be checked by measuring the belt deflection. Press on the belt with the engine stopped to measure the belt deflection, which should be 1/2 inch per foot of free span. The belt tension may be checked with a **belt tension gauge** placed over the belt (Figure 10-2). The tension on the gauge should equal the vehicle manufacturer's specifications.

If the belt requires tightening, follow this procedure:

1. Loosen the power steering pump bracket or tension adjusting bolt.
2. Loosen the power steering pump mounting bolts.
3. Check the bracket and pump mounting bolts for wear. If these bolts or bolt openings in the bracket or pump housing are worn, replacement is necessary.
4. Pry against the pump ear and hub with a pry bar to tighten the belt. Some pump brackets have a 1/2-inch square opening in which a breaker bar may be installed to move the pump and tighten the belt.
5. Hold the pump in the position described in step 4, and tighten the bracket or tension adjusting bolt.
6. Recheck the belt tension with the tension gauge. If the belt does not have the specified tension, repeat steps 1 through 5.
7. Tighten the tension adjusting bolt and the mounting bolts to the manufacturer's specified torque.

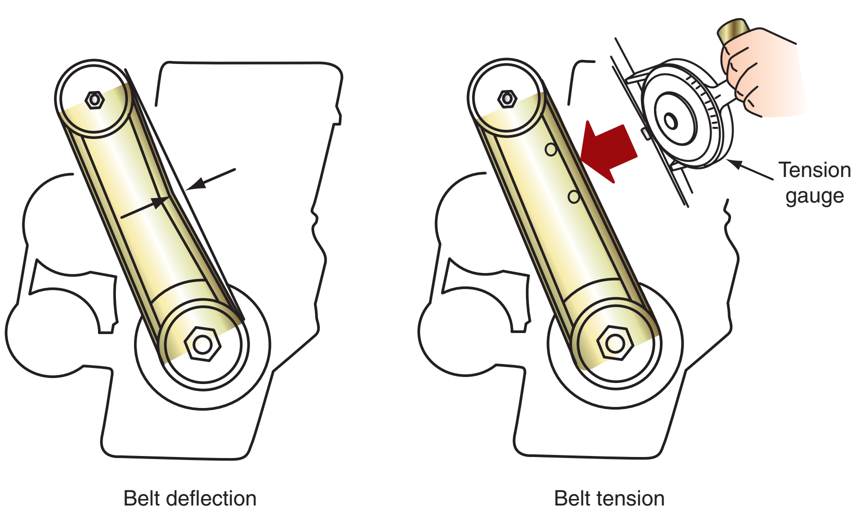

FIGURE 10-2 **Methods of checking belt tension.**

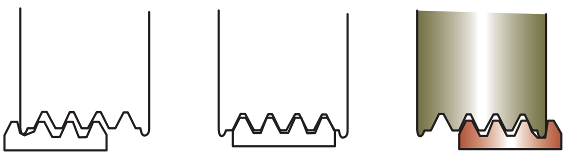

FIGURE 10-3 **Proper and improper installation of ribbed V-belt on a pulley.**

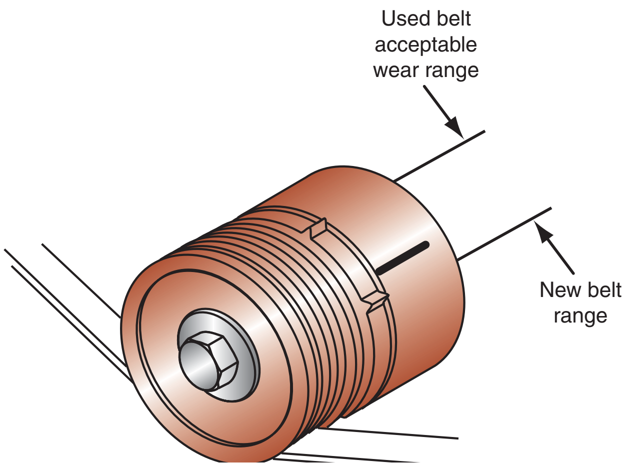

FIGURE 10-4 **Belt tension scale.**

Some power steering pumps have a **ribbed V-belt** (or **serpentine belt**). Many ribbed V-belts have an automatic tensioning pulley; therefore, a tension adjustment is not required. The ribbed V-belt should be checked to make sure it is installed properly on each pulley in the belt drive system (Figure 10-3). The tension on a ribbed V-belt may be checked with a belt tension gauge in the same way as the tension on a V-belt.

Many ribbed V-belts have a spring-loaded tensioner pulley that automatically maintains belt tension. As the belt wears or stretches, the spring moves the tensioner pulley to maintain the belt tension. Some of these tensioners have a belt length scale that indicates the new belt range and used belt range (Figure 10-4). If the indicator on the tensioner is out of the used belt length range, belt replacement is required. Many belt tensioners have a 1/2-inch drive opening in which a ratchet or flex handle may be installed to move the tensioner pulley off the belt during belt replacement (Figure 10-5).

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Belt pulleys must be properly aligned to minimize belt wear. The edges of the pulleys must be in line when a straightedge is placed on the pulleys (Figure 10-6). Repeated belt failure may be caused by a misaligned power steering pump pulley or by extremely high pump pressure caused by a sticking pressure relief valve or a continual or intermittent restriction in the high pressure hose.

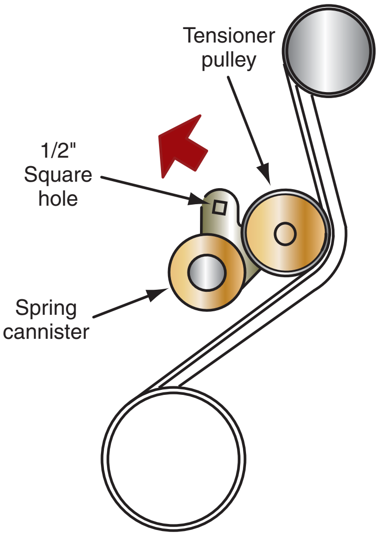

FIGURE 10-5 **One-half inch drive opening in the tensioner pulley.**

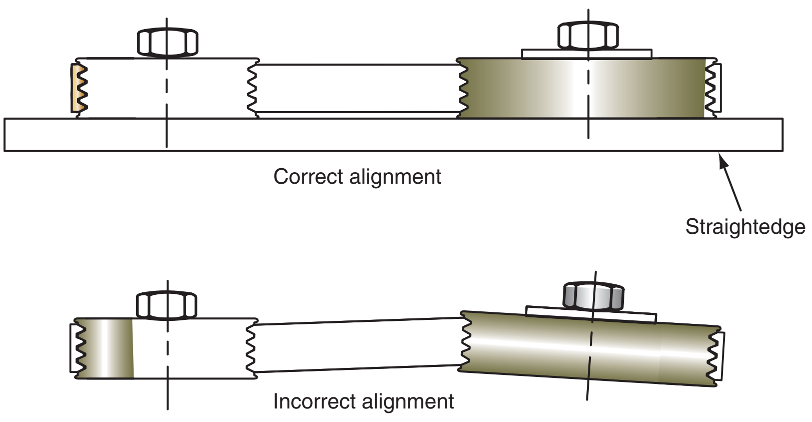

FIGURE 10-6 **Checking pulley alignment.**

CUSTOMER CARE: When servicing vehicles, always promote preventive maintenance to the customer. For example, if you are performing some underhood service, such as replacing a battery and starting motor, always make a quick inspection of the belt or belts and cooling system hoses. If you see a ribbed V-belt with chunks out of it, recommend a belt replacement to the customer. The customer will usually appreciate this service and authorize the belt replacement. If you ignore the belt with chunks out of it, and the belt breaks the next day while the customer is driving on the freeway, the customer is inconvenienced and has to pay a tow bill. Although you did a satisfactory battery and starting motor replacement, the customer will not be happy if this problem occurs the day after you worked on the vehicle. The next time this unhappy customer requires automotive service, he or she may take the vehicle to another repair shop.

POWER STEERING PUMP FLUID SERVICE

Fluid Level Inspection

Steering effort is the amount of effort required by the driver to turn the steering wheel.

Most car manufacturers recommend power steering fluid or automatic transmission fluid in power steering systems. Always use the type of power steering fluid recommended in the vehicle manufacturer's service manual. If the power steering fluid level is low, **steering effort** is increased and may be erratic. A low fluid level may cause a growling noise in the power steering pump. Some car manufacturers now recommend checking the power steering pump fluid level with the fluid at an ambient temperature of 176°F (80°C).

Follow these steps to check the power steering fluid level:

1. With the engine idling at 1,000 rpm or less, turn the steering wheel slowly and completely in each direction several times to boost the fluid temperature (Figure 10-7).
2. If the vehicle has a remote power steering fluid reservoir, check for foaming in the reservoir, which indicates low fluid level or air in the system.
3. Observe the fluid level in the remote reservoir. This level should be at the hot full mark. Shut off the engine, and remove dirt from the neck of the reservoir with a shop towel. If the power steering pump has an integral reservoir, the level should be at the hot level on the dipstick. When an external reservoir is used, the dipstick is located in the external reservoir (Figure 10-8).

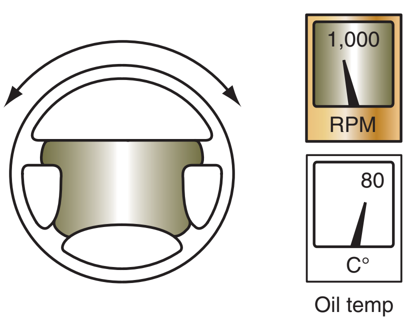

FIGURE 10-7 **Boosting fluid temperature.**

FIGURE 10-8 **Power steering pump dipstick.**

4. Pour the required amount of the car manufacturer's recommended power steering fluid into the reservoir to bring the fluid level to the hot full mark on the reservoir or dipstick with the engine idling.

Power Steering System Draining and Flushing

If the power steering fluid is contaminated with moisture, dirt, or metal particles, the system must be drained and new fluid installed.

Follow these steps to drain and flush the power steering system:

1. Lift the front of the vehicle with a floor jack and install safety stands under the suspension. Lower the vehicle onto the safety stands, and remove the floor jack.
2. Remove the return hose from the **remote reservoir** that is connected to the steering gear. Place a plug on the reservoir outlet and position the return hose in an empty drain pan (Figure 10-9).
3. With the engine idling, turn the steering wheel fully in each direction and stop the engine (Figure 10-10).
4. Fill the reservoir to the hot full mark with the manufacturer's recommended fluid.
5. Start the engine, and run the engine at 1,000 rpm while observing the return hose in the drain pan. When fluid begins to discharge from the return hose, shut the engine off.
6. Repeat steps 4 and 5 until there is no air in the fluid discharging from the return hose.
7. Remove the plug from the reservoir and reconnect the return hose. Bleed the power steering system.

CAUTION: Always use the vehicle manufacturer's recommended power steering fluid. Using the wrong power steering fluid may cause improper power steering operation.

A **remote reservoir** is mounted externally from the power steering pump.

Bleeding Air from the Power Steering System

When air is present in the power steering fluid, a growling noise may be heard in the pump and steering effort may be increased or erratic.

When a power steering system has been drained and refilled, follow this procedure to remove air from the system:

1. Fill the power steering pump reservoir as outlined previously.
2. With the engine running at 1,000 rpm, turn the steering wheel fully in each direction three or four times (Figure 10-11). Each time the steering wheel is turned fully

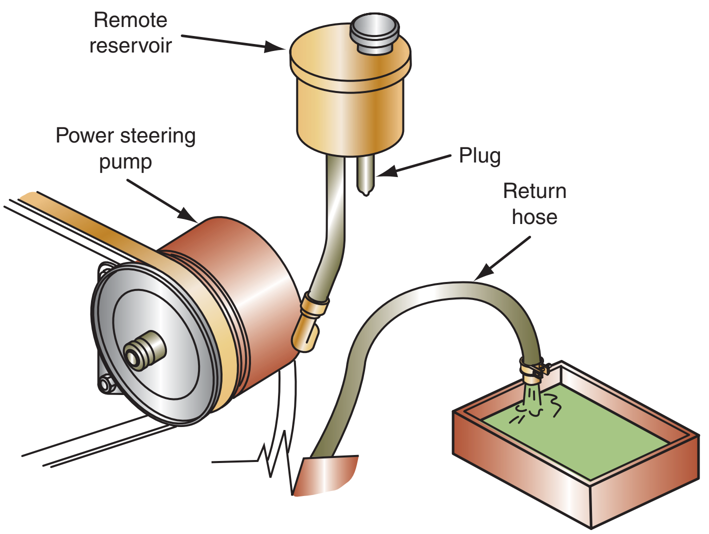

FIGURE 10-9 **Return hose installed in drain pan for power steering draining and flushing.**

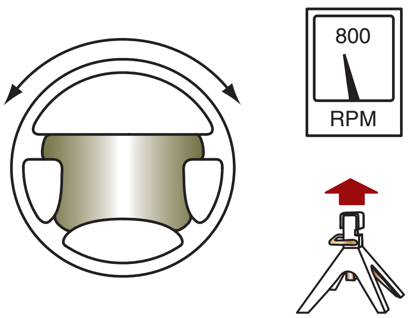

FIGURE 10-10 **Draining fluid from the power steering system.**

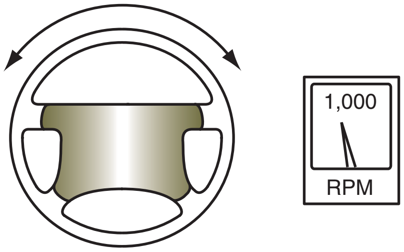

FIGURE 10-11 **Turning the steering wheel slowly to bleed air from the power steering system.**

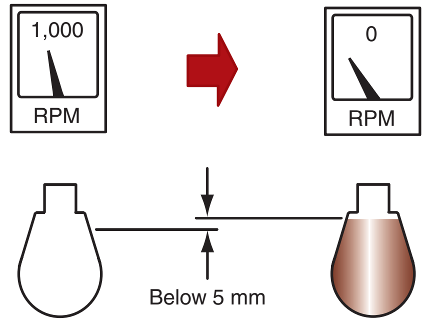

FIGURE 10-12 **Power steering fluid level after bleeding.**

to the right or left, hold it there for 2 to 3 seconds before turning it in the other direction.

3. Check for foaming of the fluid in the reservoir. When foaming is present, repeat steps 1 and 2.
4. Check the fluid level with the engine running and be sure it is at the hot full mark. Shut off the engine, and make sure the fluid level does not increase more than 0.020 in. (5 mm) (Figure 10-12).

Power Steering Bleeding Procedure with Vacuum Hand Pump

Some vehicle manufacturers recommend using a vacuum hand pump to bleed air from the power steering system. Follow this procedure to bleed the power steering system with a vacuum hand pump:

1. Remove the power steering pump reservoir cap.
2. Install a special fitting to the reservoir cap opening that allows a vacuum hose to be connected to the fitting.
3. Connect the vacuum hand pump hose to the fitting installed on the power steering pump reservoir.
4. Operate the vacuum hand pump until the vacuum gauge on the pump indicates 20 in. Hg. (68 kPa).
5. Wait for 5 minutes or vehicle manufacturer's specified time interval.
6. Release the vacuum in the hand pump and reservoir. Remove the hand pump hose and special fitting from the power steering pump.
7. Check the fluid level in the power steering pump reservoir, and correct as necessary.
8. Install the pump reservoir cap and dipstick and check the operation of the power steering system.

Power Steering Pump Diagnosis

Power Steering Pump Pressure Test

SPECIAL TOOLS
Power steering pressure test gauge

Since there are some variations in power steering pump pressure test procedures and pressure specifications, the vehicle manufacturer's test procedures and specifications must be used. If the power steering pump pressure is low, steering effort is increased. Erratic power steering pump pressure causes variations in steering effort, and the steering wheel may jerk as it is turned. Since a power steering pump will never develop the specified pressure if the

FIGURE 10-13 **Pressure gauge connection to power steering pump.**

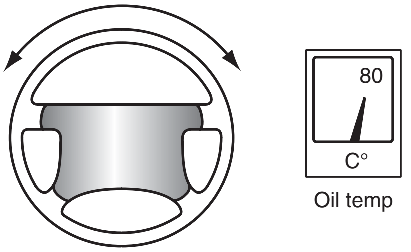

FIGURE 10-14 **Bleeding air from the power steering pump system and checking fluid temperature.**

belt is slipping, the belt tension must be checked and adjusted, if necessary, prior to a pump pressure test.

The following is a typical power steering pressure test procedure:

1. With the engine stopped, disconnect the pressure line from the power steering pump and connect the gauge side of the **pressure gauge** to the pump outlet fitting. Connect the valve side of the gauge to the pressure line (Figure 10-13).
2. Start the engine, and turn the steering wheel fully in each direction two or three times to bleed air from the system (Figure 10-14). Be sure the fluid level is correct and the fluid temperature is at least 176°F (80°C). A thermometer may be inserted in the pump reservoir fluid to measure the fluid temperature.

A **pressure gauge** is designed to measure the high pressure in the power steering system.

WARNING: During the power steering pump pressure test with the engine idling, close the pressure gauge valve for no more than 10 seconds because excessive pump pressure may cause power steering hoses to rupture, resulting in personal injury.

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WARNING: Do not allow the fluid to become too hot during the power steering pump pressure test. Excessively high fluid temperature reduces pump pressure. Wear protective gloves, and always shut the engine off before disconnecting gauge fittings, because the hot fluid may cause burns.

3. With the engine idling, close the pressure gauge valve for no more than 10 seconds, and observe the pressure gauge reading (Figure 10-15). Turn the pressure gauge valve to the fully open position. If the pressure gauge reading does not equal the vehicle manufacturer's specifications, repair or replace the power steering pump.
4. Inspect the power steering pump pressure with the engine running at 1,000 rpm and 3,000 rpm, and record the pressure difference between the two readings (Figure 10-16). If the pressure difference between the pressure readings at 1,000 rpm and 3,000 rpm does not equal the vehicle manufacturer's specifications, repair or replace the **flow control valve** in the power steering pump.

The **flow control valve** controls power steering fluid flow from the pump to the steering gear.

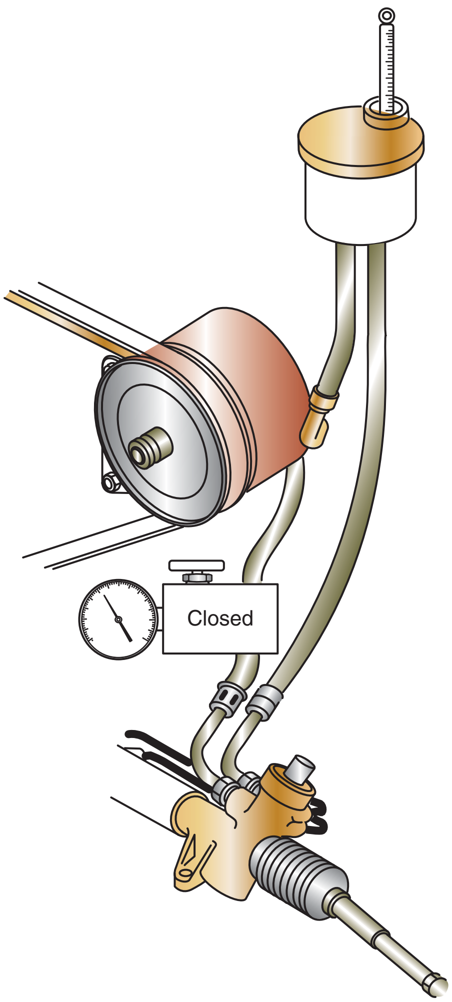


FIGURE 10-15 **Power steering pump pressure test with pressure gauge valve closed.**

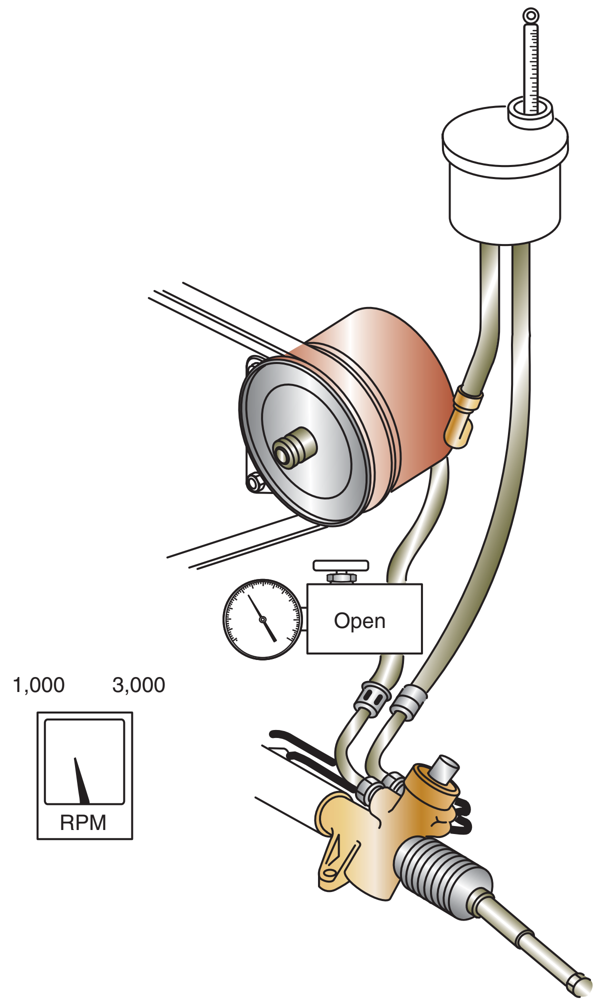


FIGURE 10-16 **Power steering pump pressure test at 1,000 and 3,000 rpm.**

5. With the engine running, turn the steering wheel fully in one direction and observe the steering pump pressure while holding the steering wheel in this position (Figure 10-17). If the pump pressure is less than the vehicle manufacturer's specifications, the steering gear housing has an internal leak and should be repaired or replaced.
6. Be sure the front tire pressure is correct and center the steering wheel with the engine idling. Connect a spring scale to the steering wheel and measure the steering effort in both directions (Figure 10-18). If the power steering pump pressure is satisfactory and the steering effort is more than the vehicle manufacturer's specifications, the power steering gear should be repaired. Photo Sequence 17 shows a typical procedure for pressure testing a power steering pump.

SPECIAL TOOLS
Spring scale

Power Steering Pump Oil Leak Diagnosis

The possible sources of power steering pump oil leaks are the driveshaft seal, reservoir O-ring seal, high-pressure outlet fitting, and the dipstick cap. If leaks occur at any of the seal locations, seal replacement is necessary. When a leak is present at the high-pressure outlet fitting, tighten this fitting to the specified torque (Figure 10-19). If the leak still occurs, replace the O-ring seal on the fitting and retighten the fitting.

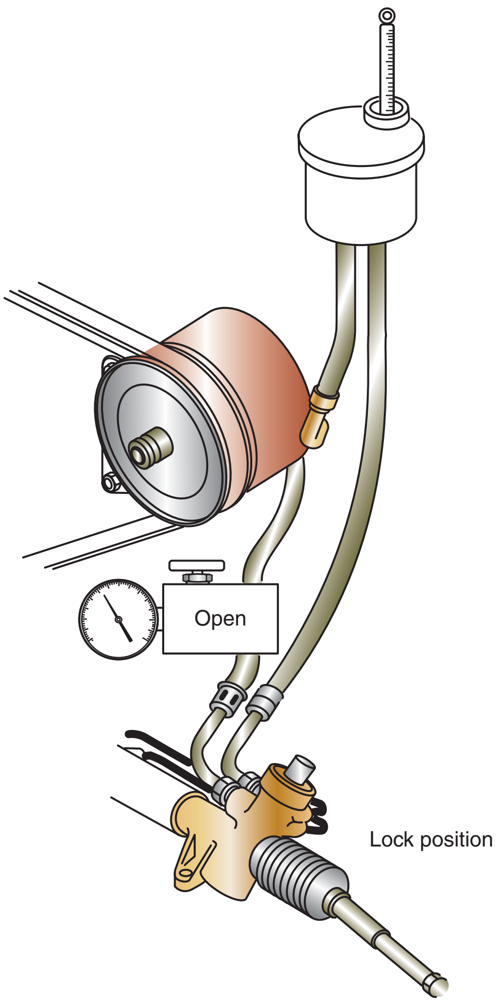


FIGURE 10-17 **Power steering pump pressure test with the front wheels turned fully in one direction.**

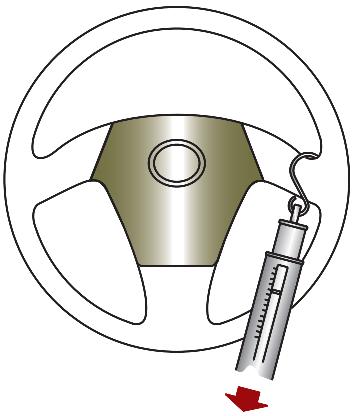


FIGURE 10-18 **Steering effort measurement.**

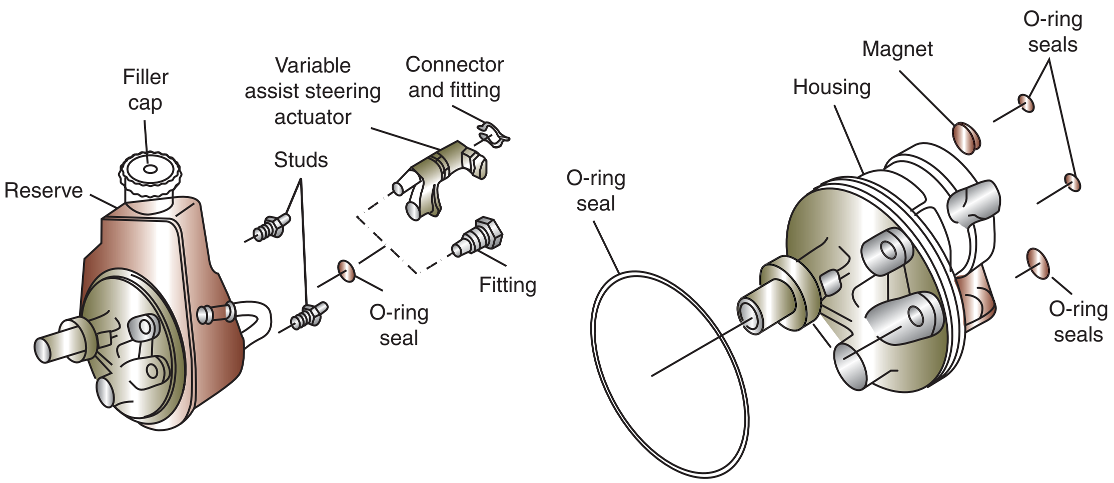
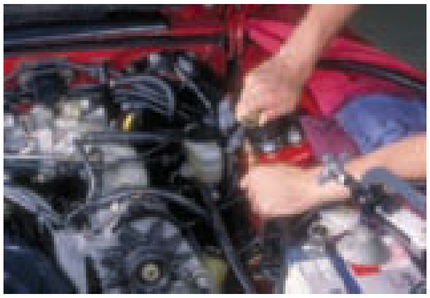


FIGURE 10-19 **Power steering pump oil leak diagnosis.**

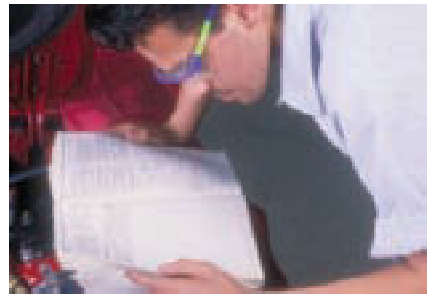
PHOTO SEQUENCE 17

Typical Procedure for Pressure Testing a Power Steering Pump



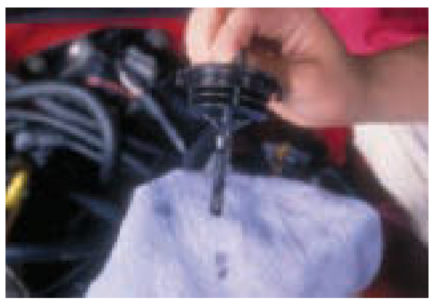
P17-1 Connect the pressure gauge to the power steering pump.

P17-2 Connect a tachometer to the ignition system.



P17-3 Look up the vehicle manufacturer's specified power steering pump pressure in the service manual.

P17-4 Start the engine, and turn the steering wheel from lock to lock three times to bleed air from the system and heat the power steering fluid.

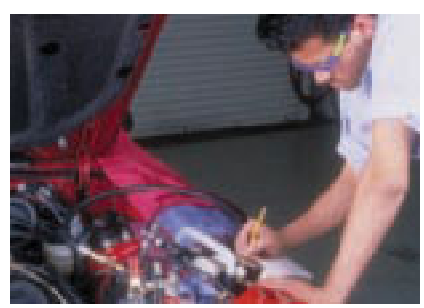


P17-5 Check the power steering fluid level, and add fluid as required.

P17-6 Place a thermometer in the power steering fluid reservoir. Be sure the fluid temperature is at least 176°F (80°C).

P17-7 With the engine idling, close the pressure gauge valve for no more than 10 seconds. Observe and record the pressure gauge reading.

P17-8 Check and record the power steering pump pressure at 1,000 rpm.



P17-9 Check and record the power steering pump pressure at 3,000 rpm.

P17-10 **Check and record the power steering pump pressure with the steering wheel turned fully in one direction and the engine idling.**

Power Steering Pump Service

Power Steering Pump Replacement

WARNING: If the vehicle has been driven recently, the pump, hoses, and fluid could be extremely hot. Use caution when handling components to avoid burns.

If a growling noise is present in the power steering pump after the fluid level is checked and air has been bled from the system, the pump bearings or other components are defective and pump replacement or repair is required. When the power steering pump pressure is lower than specified, pump replacement or repair is necessary.

SPECIAL TOOLS
Puller for power steering pump pulley, press-on pulley

SPECIAL TOOLS
Power steering pump pulley installing tool, press-on pulley

To replace the power steering pump, proceed as follows:

1. Disconnect the power steering return hose from the remote reservoir or pump. Allow the fluid to drain from this hose into a drain pan. Discard the used fluid.
2. Loosen the bracket or belt tension adjusting bolt and the pump mounting bolt.
3. Loosen the belt tension until the belt can be removed. On some cars, it is necessary to lift the vehicle on a hoist and gain access to the power steering pump from underneath the vehicle.
4. Remove the hoses from the pump and cap the pump fittings and hoses.
5. Remove the belt tension adjusting bolt and the mounting bolt, and remove the pump.
6. Check the pump mounting bolts and bolt holes for wear. Worn bolts must be replaced. If the bolt mounting holes in the pump are worn, pump replacement is necessary.
7. Reverse steps 1 through 5 to install the power steering pump. Tighten the belt as described previously, and tighten the pump mounting and bracket bolts to the manufacturer's specifications. If O-rings are used on the pressure hose, replace the O-rings. Be sure the hoses are not contacting the exhaust manifold, catalytic converter, or exhaust pipe during or after pump replacement.
8. Fill the pump reservoir with the manufacturer's recommended power steering fluid and bleed air from the power steering system as described earlier.

Power Steering Pump Pulley Replacement

If the pulley wobbles while it is rotating, the pulley is probably bent, and pulley replacement is necessary. Worn pulley grooves also require pulley replacement. Always check the pulley

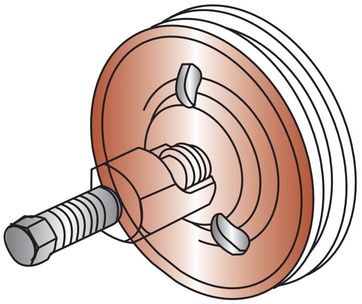


FIGURE 10-20 **Press-on power steering pump pulley removal.**

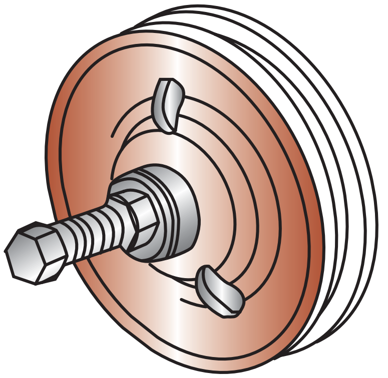


FIGURE 10-21 **Press-on power steering pump pulley installation.**

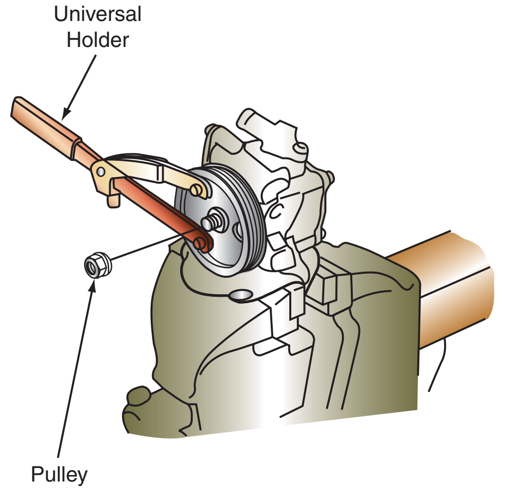


FIGURE 10-22 **Removing power steering pump pulley and nut.**

A **woodruff key** is a half-moon shaped key that fits snugly in a shaft opening, with the top edge of the key extending out of the shaft. The top edge of the key fits snugly in a groove cut inside the pulley hub. When the pulley is installed on the shaft, the pulley groove slides over the key to prevent pulley rotation on the shaft.

An **integral reservoir** is mounted on the power steering pump.

Crocus cloth is a very fine polishing-type emery paper.

for cracks. If this condition is present, pulley replacement is essential. A pulley that is loose on the pump shaft must be replaced. Never hammer on the pump drive shaft during pulley removal or replacement. This action will damage internal pump components. If the pulley is pressed onto the pump shaft, a special puller is required to remove the pulley (Figure 10-20), and a pulley installation tool is used to install the pulley (Figure 10-21).

If the power steering pump pulley is retained with a nut, mount the pump in a vise. Always tighten the vise on one of the pump mounting bolt surfaces. Do not tighten the vise with excessive force. Use a special holding tool to keep the pulley from turning, and loosen the pulley nut with a box end wrench (Figure 10-22). Remove the nut, pulley, and **woodruff key**. Inspect the pulley, shaft, and woodruff key for wear. Be sure the key slots in the shaft and pulley are not worn. Replace all worn components.

Remove and Replace the Power Steering Pump Reservoir

Power steering pump service procedures vary depending on the type of pump. Always follow the vehicle manufacturer's recommended service procedures in the service manual. The following service procedures are for a power steering pump with an **integral reservoir**.

When the power steering pump has an integral reservoir, follow these steps for reservoir removal and replacement:

1. Remove the filler cap and drain the oil from the reservoir.
2. Remove the two clips that retain the reservoir to the housing.
3. Rock the reservoir by hand or tap it gently with a soft hammer to remove it from the housing.
4. Clean all the parts and discard the O-ring. Inspect the O-ring surfaces for damage.
5. Lubricate the new O-ring with the manufacturer's recommended power steering fluid and install it (Figure 10-23).
6. Install the reservoir and retaining clips.

Remove and Replace Flow Control Valve and End Cover

When the flow control valve and end plate are serviced, follow these steps:

1. Remove the retaining ring with a slotted screwdriver and a punch (Figure 10-24).
2. Remove the flow control valve, end cover, spring, and magnet. Inspect the flow control valve for burrs. Remove minor burrs with **crocus cloth** and clean the flow control

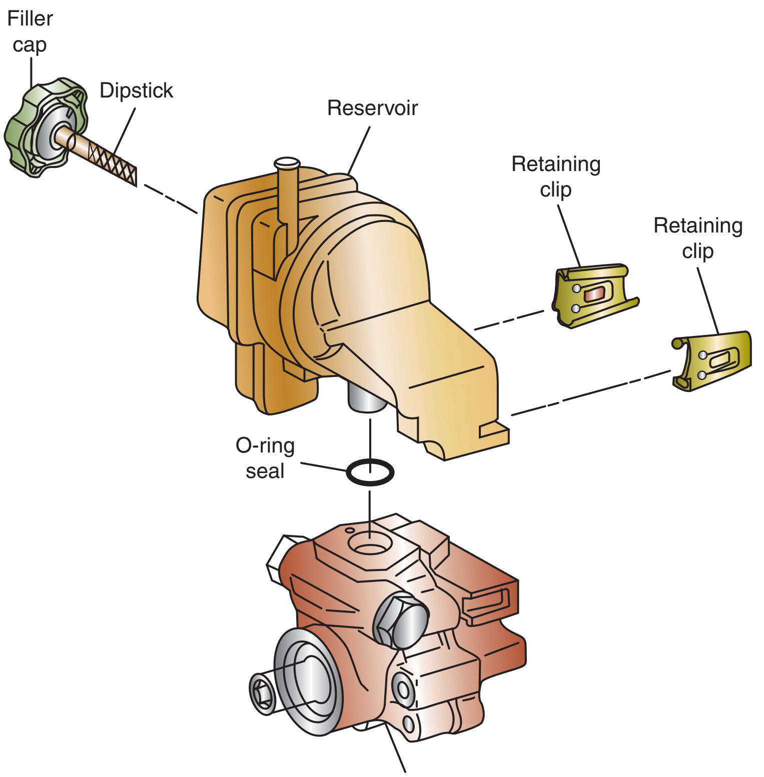


FIGURE 10-23 **Integral power steering pump reservoir seal and O-ring.**

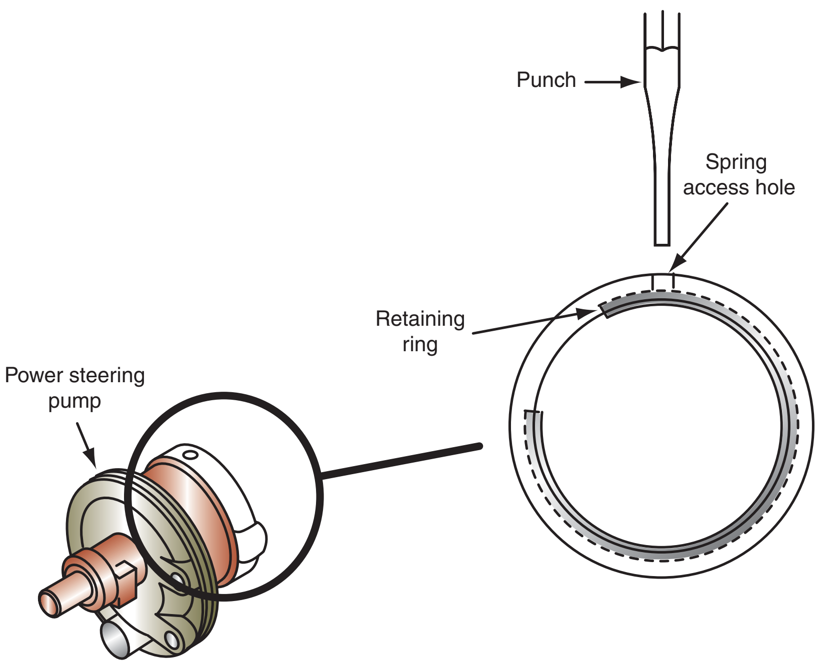


FIGURE 10-24 **Retaining ring removal.**

valve in solvent. Damaged or worn flow control valves must be replaced. Inspect the end cover sealing surface for damage. Inspect the pump driveshaft for corrosion and damage. Remove corrosion with crocus cloth (Figure 10-25). Clean the magnet with a shop towel.

3. Clean all parts and lubricate the end cover with power steering fluid.
4. Install the end cover, retaining ring, and related components.

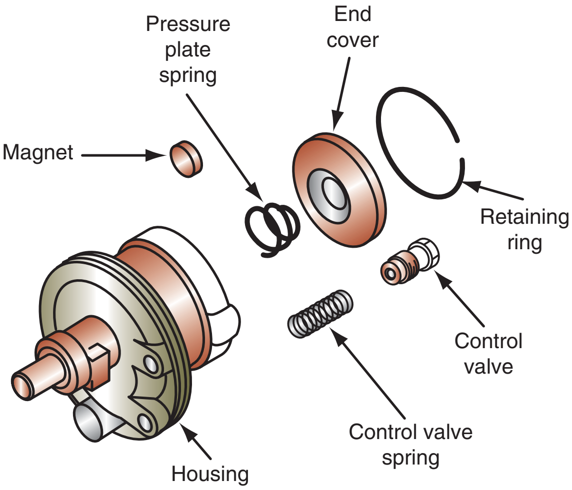


FIGURE 10-25 **End cover and related component service.**

Remove and Replace Pressure Relief Valve

The **pressure relief valve** limits the maximum power steering pump pressure.

Follow this procedure to service the pressure relief valve:

1. Wrap a shop towel around the land end of the flow control valve and clamp this end in a soft-jawed vise. Be very careful not to mark valve lands.
2. Remove the hex-head ball seat (Figure 10-26). Clean the components in solvent. A worn or damaged pressure relief ball, spring, guide, or seat must be replaced.

Inspecting and Servicing Power Steering Lines and Hoses

Power steering lines should be inspected for leaks, dents, sharp bends, cracks, and contact with other components. Lines and hoses must not rub against other components. This action could wear a hole in the line or hose. Many high-pressure power steering lines are made from high-pressure steel-braided hose with molded steel fittings on each end (Figure 10-27).

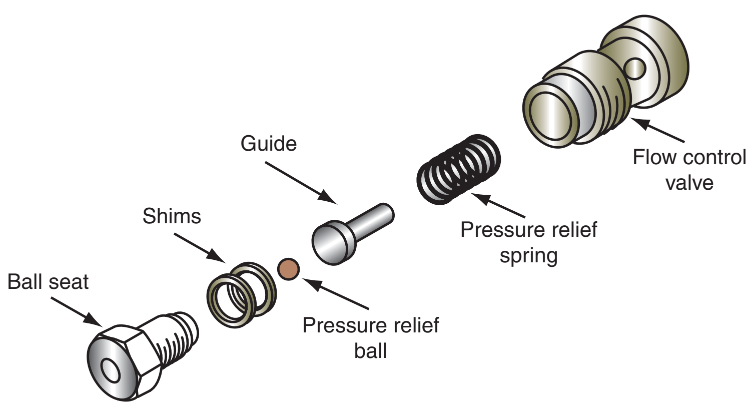


FIGURE 10-26 **Pressure relief valve removal.**

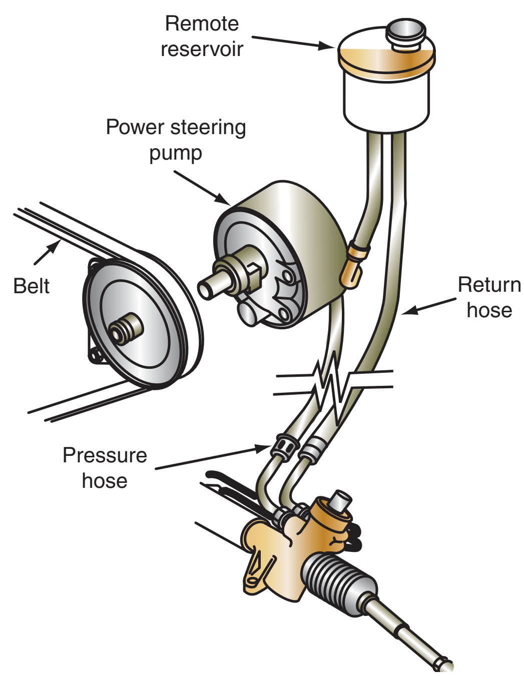


FIGURE 10-27 **Power steering hoses and lines.**

Power Steering Hose Replacement

WARNING: If the engine has been running, the power steering hoses, components, and fluid may be extremely hot. Wear protective gloves and use caution to avoid burns.

When power steering hose replacement is required, follow these steps:

1. With the engine stopped, remove the return hose at the power steering gear, and allow the fluid to drain from this hose into a drain pan. On some cars, the vehicle must be lifted on a hoist to replace the power steering hoses.
2. Loosen and remove all hose fittings from the pump and steering gear.
3. Remove all hose-to-chassis clips.
4. Remove the hoses from the chassis and cap the pump and steering gear fittings.
5. If O-rings are used on the hose ends, install new O-rings.
6. Reverse steps 1 through 4 to install the power steering hoses. Tighten all fittings to the manufacturer's specified torque. Be sure all hose-to-chassis clips are in place. Do not position hoses where they rub on other components.
7. Fill the pump reservoir to the full mark with the manufacturer's recommended fluid. Bleed air from the power steering system, as mentioned previously in this chapter. Check the fluid level in the reservoir and add fluid as required.

Refer to Table 10-1 for steering colum and steering linkage diagnosis

TABLE 10-1 **STEERING COLUMN AND STEERING LINKAGE DIAGNOSIS**

Problem	Symptoms	Possible Causes
Underhood noise	Squealing noise during engine acceleration or during steering wheel rotation	Loose power steering pump belt
	Squealing and chirping noise with the engine idling	Dry power steering pump belt friction surfaces
	Growling noise with engine idling	Low power steering fluid level Air in the power steering fluid
Improper steering wheel turning effort	Erratic steering wheel turning effort while cornering	Loose power steering pump belt Low power steering fluid level Air in the power steering fluid
	Excessive steering wheel turning effort	Loose power steering pump drive belt Low power steering fluid level Low power steering pump pressure
Power steering pump fluid leaks	Fluid leaks at the drive shaft behind the pulley	Worn drive shaft seal
	Fluid leaks between the reservoir and the housing	Leaking reservoir O-ring
	Fluid leaks at the back of the reservoir	Leaking O-ring seals or pump-to-line fittings
Rapid power steering belt wear	Power steering belt wears out prematurely	Misalignment of power steering pump pulley, and other pulleys driven by the same belt Excessive power steering belt tension

Hybrid Electric Vehicle (HEV) and Electrohydraulic Power Steering (EHPS) Diagnosing and Servicing Procedures

HEV Service Precautions

Most HEVs have high-voltage electrical systems that pose a severe electrical shock hazard for anyone servicing these vehicles. When servicing HEV electrical systems, always follow these precautions:

1. Wear high-voltage electrical lineman's gloves rated at 1,000 V. Inspect these gloves periodically to be sure they do not contain pin holes or other damage. Immediately replace all damaged gloves.
2. When working on an HEV, always be sure the HEV system is deactivated by removing the electronic or conventional key from the instrument panel. This action prevents the engine from starting.
3. Turn the high-voltage circuit switch off to isolate the battery pack from the electrical system (Figure 10-28). Some HEV manufacturers recommend removing the 20-A yellow HEV fuse in the underhood fuse block (Figure 10-29).
4. Disconnect the negative cable on the 12-V battery (Figure 10-30).
5. After the disabling procedure on some HEVs, power is maintained in the SRS system for 90 seconds and in the high-voltage system for 5 minutes. After disabling the electrical system, always wait for the time period specified by the vehicle manufacturer.

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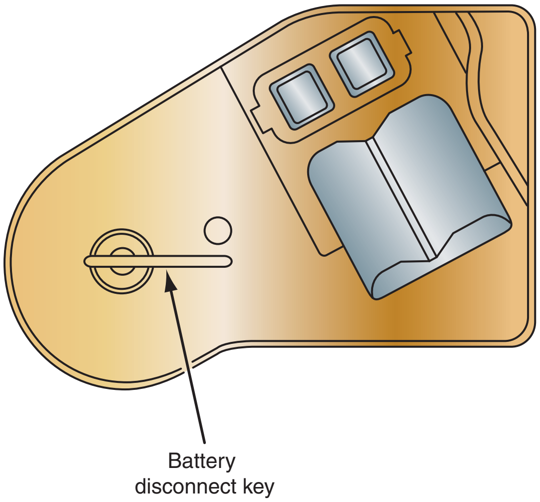

FIGURE 10-28 **Battery disconnect key in the ESB.**

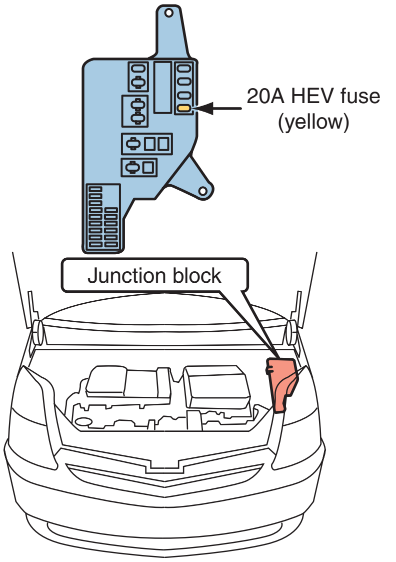

FIGURE 10-29 **Removing HEV fuse from fuse block.**

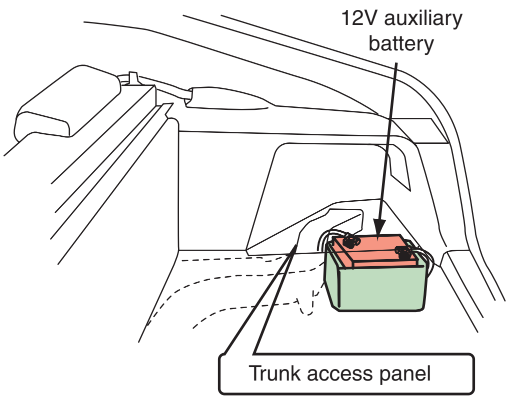

FIGURE 10-30 **Disconnecting the 12-V battery.**

6. Be sure the high- and low-voltage systems have been disabled before using welding equipment on the vehicle. If the HEV system is not disabled, the welding equipment may send high-voltage spikes through the system resulting in component damage.
7. If the battery pack has experienced collision or other damage and battery pack leakage is suspected, wear protective gloves and safety goggles when servicing the battery pack. Nickel–metal hydride batteries contain potassium hydroxide a highly alkaline solution that damages human tissue. Battery pack leakage may be sprayed with vinegar to neutralize the solution.
8. Inspect high-voltage (orange) cables for frayed insulation and damage which could result in electrical shocks, sparks, and fires. Frayed, damaged orange cables must be replaced.
9. If HEVs are towed with the drive wheels on the road surface, the generator may begin producing voltage and current even if the high-voltage electrical system is disabled. This may result in sparks and a fire.
10. The battery packs in many HEVs contain nickel–metal hydride type batteries. These batteries self-discharge quickly compared with a conventional lead acid battery. A nickel–metal hydride battery may lose 30 percent of its charge per month. Do not leave an HEV sitting for 2 or 3 months without starting the engine. If an HEV is not being driven, the engine should be started and allowed to run for 30 minutes every 2 or 3 weeks to maintain the battery pack state of charge. Some test equipment manufacturers are designing battery chargers for HEV battery packs, but this test equipment is not available at the present time. The engine must be operated to allow the generator to recharge the battery pack. Some HEVs have an auxiliary starter to start the engine if the battery pack is discharged.
11. When working on an HEV with a smart key, always be sure the smart key is removed from the instrument panel, and the disable button under the steering column is pushed to the Off position. This action prevents the HEV system from being activated by pressing the smart key when it is located in close proximity to the vehicle.
12. Use caution when hoisting or lifting HEVs to avoid damage to the high-voltage cable compartments and cables.
13. On HEVs the refrigerant oil specified by the vehicle manufacturer such as SE 10-Y, ND-OIL, 11 must be used in the AC system. Many HEVs have an electric-drive AC compressor that remains operational during the engine stop mode to maintain AC system operation. In many of these compressors, 300 V from the inverter is supplied to the compressor drive motor. This higher voltage requires lower amperes of current through the compressor clutch coil. The refrigerant oil in these compressors must have special insulating qualities or the high-voltage insulation inside the compressor may be damaged.

Starting/Stopping Procedures and Warning Indicators

Technicians must be familiar with the proper starting and stopping procedures and warning indicators on HEVs. The engine starting/stopping procedures and warning indicators may vary on hybrid vehicles depending on the vehicle and model year. Always refer to the vehicle manufacturers' information. The following procedures and indicators are typical. Some hybrid vehicles have an electronic key that fits into a key slot in the dash. A power button and an indicator light are located above the electronic key slot in the dash (Figure 10-31). The power button is pressed to cycle through the ignition modes rather than rotating the electronic key in the slot. The electronic key also contains the remote keyless entry buttons and a hidden metal key (Figure 10-32).

The doors are unlocked and locked by pressing the appropriate buttons on the electronic key. Another option for opening the doors is to remove the hidden metal key from the electronic key, and insert the metal key into the key cylinder in the drivers' door. Rotating the metal key once unlocks the drivers' door, and rotating this key a second time unlocks the other doors. There are no lock cylinders in the other doors.

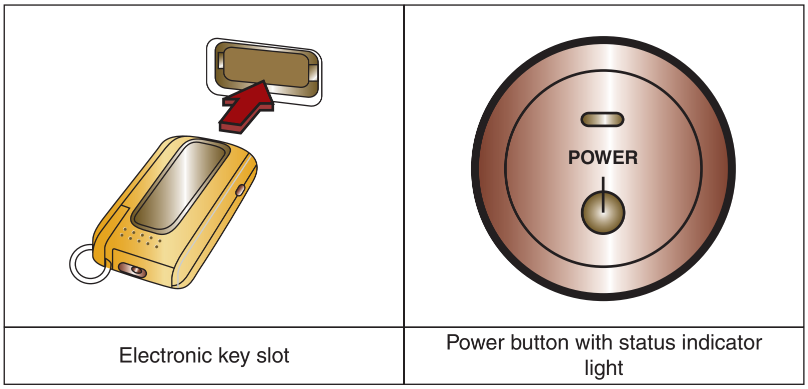

FIGURE 10-31 **Electronic key and power button.**

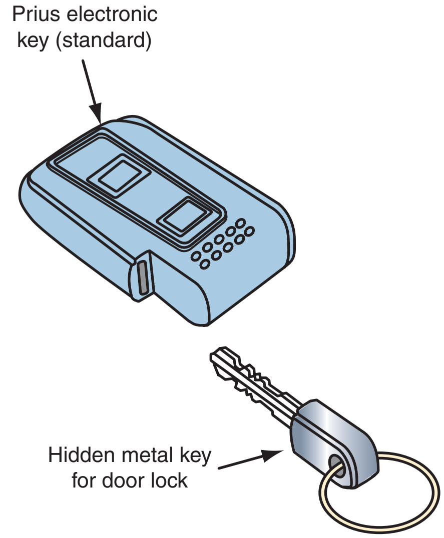

FIGURE 10-32 **Electronic key with remote keyless entry button and hidden metal key.**

To activate the HEV system and other electronic systems, insert the electronic key into the slot in the dash. With the brake pedal released, pressing the power button once turns on the accessory mode, and pushing the power button again turns on the ignition mode. Pressing the power button a third time turns the ignition off. When the ignition mode is off, the power button indicator light is also off. In the accessory mode the power button indicator light is green, and in the ignition mode this light is amber. When a defect occurs in the electrical system, the amber power button light starts blinking.

With the brake pedal depressed, pressing the power button once activates the HEV and other electronic systems. Starting the vehicle takes priority over all other modes. When the HEV system is activated, the power button indicator light goes off and the Ready light in the instrument panel is illuminated (Figure 10-33). When starting off under light load conditions,

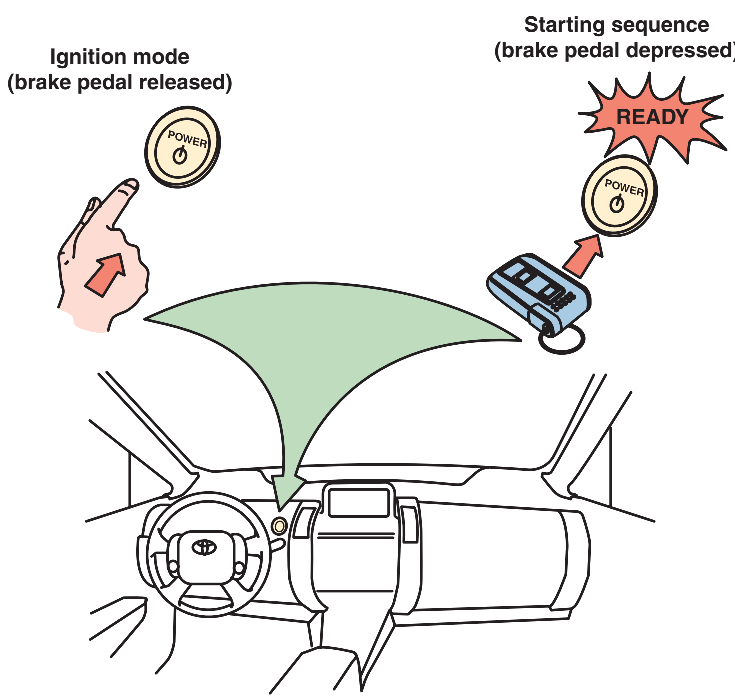

FIGURE 10-33 **Ignition modes and starting sequence.**

the engine does not start because the vehicle is only driven by the propulsion motor. Never work on an HEV with the electronic key installed in the dash and the HEV system activated. Under this condition, the engine may start and cause personal injury and/or vehicle component damage if the battery pack voltage reaches a specific discharged state. To shut off the vehicle, bring the vehicle to a complete stop and press the power button once and remove the electronic key. When the Ready light is illuminated, the electronic key cannot be removed from the key slot.

The vehicle may have an optional smart entry system with a smart electronic key. This key contains a transceiver that communicates bidirectionally and allows the vehicle to recognize the smart key in close proximity to the vehicle. The smart entry and smart key can unlock and lock the doors without pushing the buttons on the smart key. This system can also start the hybrid system without inserting the smart key into the dash slot. If the smart key is in close proximity to the vehicle, the doors may be unlocked by touching the sensor on the backside of either exterior front door handle (Figure 10-34). Press the black lock button on either exterior front door handle to lock the doors. If the smart key is in close proximity to the vehicle, the normal ignition modes and start mode are operational. The smart key also contains a hidden metal key. Vehicles equipped with a smart key and smart entry system have a disabling button located in the dash under the steering column. If the disable button is pressed, the smart key must be inserted into the key slot to activate the ignition modes and start the vehicle (Figure 10-35).

The speedometer, gear shift indicator, Ready light, fuel gauge, and warning lights are located in a digital display in the center of the dash near the base of the windshield. An LCD monitor located at the top, center of the dash displays fuel consumption, A/C controls, and energy monitor (Figure 10-36). The electronic gearshift selector is a momentary select, shift-by-wire system that engages the transaxle in Reverse, Neutral, Drive, or engine Brake modes. There are no mechanical connections between the dash indictors and the transaxle. The dash indicator also informs the driver regarding the gear selected (Figure 10-37). After selecting the desired gear position, the transaxle remains in that position as indicated by the dash display, but the shift selector returns to a default mode. When the vehicle is stopped, Park may be selected by pressing the P switch in the dash display. If the power button is pressed to shut off the vehicle, Park is automatically engaged. Voltage is supplied to the gearshift selector and the electromechanical parking pawl by the 12-V battery. If the 12-V battery is discharged, or disconnected, the vehicle cannot be started or shifted out of park.

When the Ready light is illuminated, the vehicle is operational even though the engine is not running. The driver simply selects Drive (D) or Reverse (R) on the gearshift selector, releases

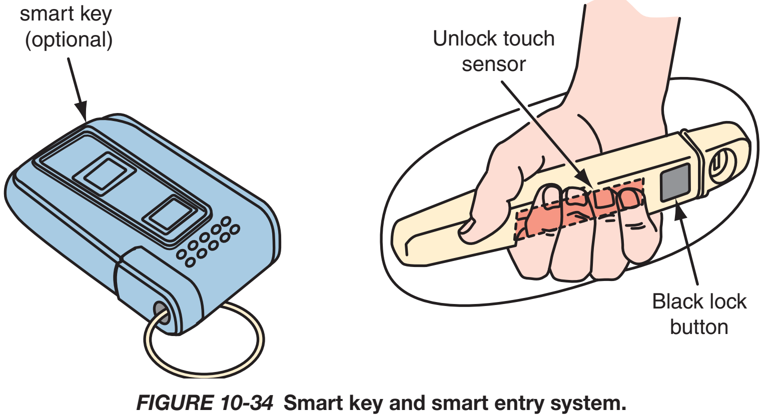

FIGURE 10-34 Smart key and smart entry system.

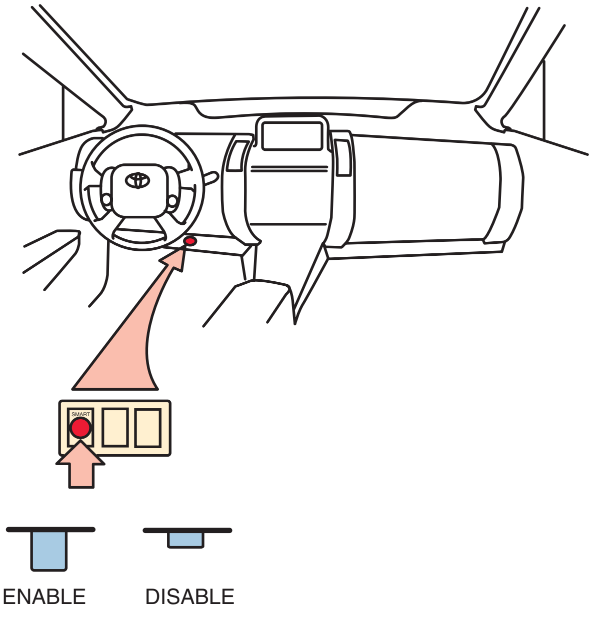

FIGURE 10-35 Disable button on smart key systems.

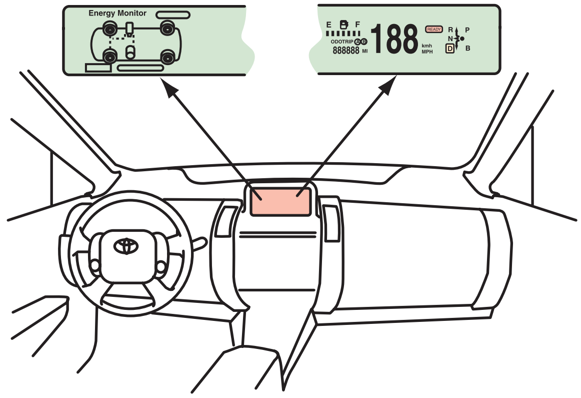

FIGURE 10-36 Digital dash displays.

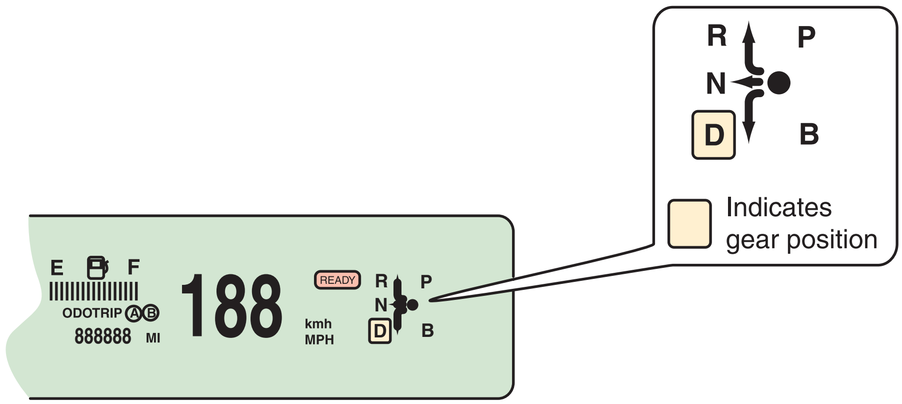

FIGURE 10-37 Gearshift indicator.

the brake pedal, and steps on the accelerator pedal to begin driving the vehicle. The vehicle computer decides when to start and stop the engine depending on many factors such as vehicle load and speed, and battery pack state of charge. A hybrid vehicle does not have the usual noise associated with starting motor operation, because the battery simply passes current through the generator windings to rotate and start the engine. The vehicle computer stops the engine during deceleration below a specific speed, and during idle operation, to improve fuel economy.

Scan Tool Diagnosis of HEV and EHPS Systems

To begin the HEV system diagnosis, visually inspect all HEV system components, wiring harnesses, and connectors. Any damaged components, wiring harnesses, or connectors should be replaced. The orange high-voltage cables may be checked for high-voltage leakage by using a digital volt-ohm meter (DVOM). With the DVOM on the highest DC voltage scale, connect the negative DVOM lead to ground on the vehicle chassis, and move the red lead along the high-voltage cable surfaces. High-voltage leakage causes a reading on the voltmeter. A scan tool may be used to diagnose the HEV system. HEV system diagnosis varies depending on the vehicle make and model year. Always use the vehicle manufacturer's specific diagnostic information for the vehicle being diagnosed and serviced. The following is a typical HEV diagnosis. The scan tool and the module installed in the scan tool must be compatible with the HEV system and the vehicle network(s). A special CANdi module must be used with the scan tool on some HEV systems. If the visual inspection does not indicate any HEV system problems, the scan tool may be used to perform a diagnostic system check. Follow these steps to complete the diagnostic system check:

1. Connect the scan tool to the DLC under the dash. If the scan tool does not power up, check the 12-V supply terminal and the ground terminal in the DLC.
2. Turn the ignition switch on with the engine off. Using the scan tool, attempt to establish communication with the energy storage control module (ESCM), hybrid control module

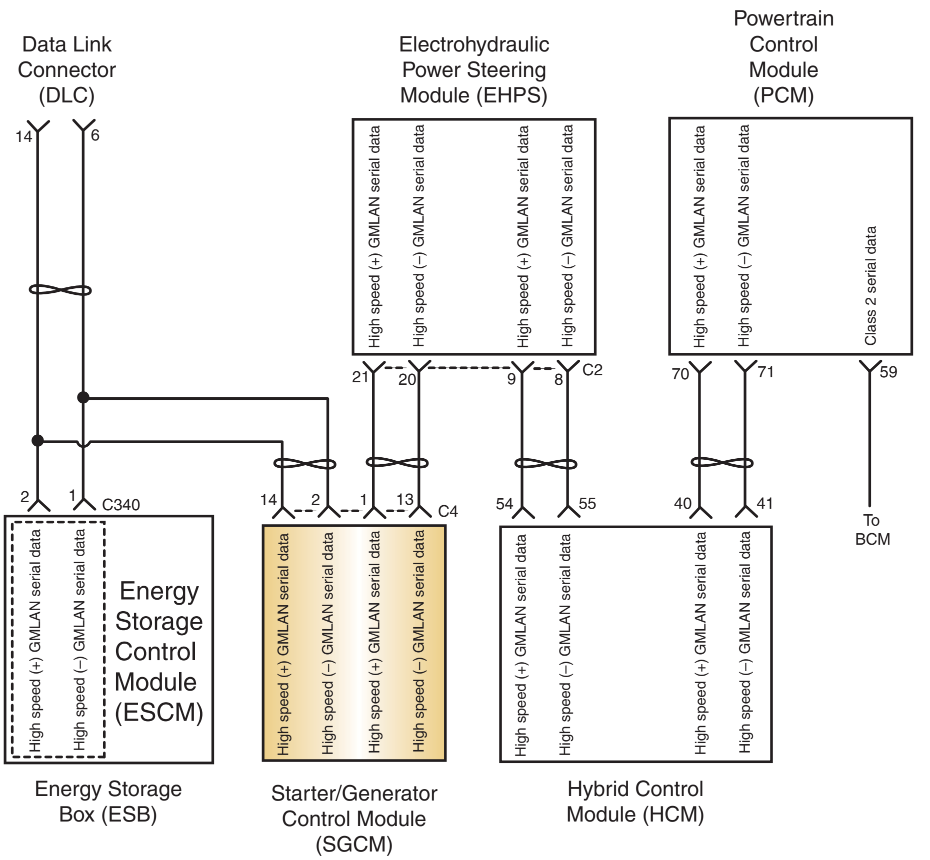

FIGURE 10-38 **The LAN bus interconnects the SGCM, PCM, EHPS moduls, ESB, and DLC.**

(HCM), and the starter/generator control module (SGCM). If the scan tool does not communicate with any of these modules, there is a problem in the LAN network and further network diagnosis is required (Figure 10-38). Refer to Chapter 8 in the Shop Manual for network diagnosis. Always follow the vehicle manufacturer's specific diagnostic procedure for the vehicle being diagnosed.

3. Use the scan tool to establish communication with the PCM. If the scan tool does not communicate with the PCM, there is a problem in the Class 2 network and further diagnosis of this network is necessary.
4. Select PCM DTC display on the scan tool. DTCs with a U prefix indicate network problems, and specific DTC diagnosis is required.
5. Check the scan tool display for PCM DTCs. When DTCs are present, the cause of the DTCs must be diagnosed and repaired.

Diagnostic example for a U0131 network DTC

Current vehicles have hundreds of DTCs, and thus it is impossible to include an interpretation and diagnostic procedure for all DTCs in this publication. A U0131 DTC is set when the communication is lost between the EHPS module and the PCM. Under this condition, the EHPS operates in a default mode. The possible causes of this DTC are as follows:

1. An open circuit in the EHPS module connector.
2. An open circuit in the LAN network.
3. An open circuit in the voltage supply or ground circuits to the EHPS module.
4. An internal module malfunction. Many modules have specific DTCs for internal module defects.

To locate the root cause of the U0131 DTC, the technician must perform tests with a DVOM or lab scope on the suspected components.

Diagnostic Example for a P0562 DTC

A P0562 DTC is set when the PCM detects an improper voltage below 11 V for 5 seconds. When this DTC is set in the PCM memory, the PCM takes these actions:

1. The PCM stores faulty circuit conditions that were present when the DTC set.
2. The PCM disables many outputs.
3. The transmission defaults to a predetermined gear.
4. Torque converter clutch lockup is inhibited.
5. The instrument panel cluster (IPC) displays a warning message.
6. The malfunction indicator light (MIL) will not illuminate.

When this DTC is present in the PCM memory, the technician must use an amp-volt tester to test the charging circuit and use a DVOM to test all the electrical circuits between the charging circuit, battery, and PCM to locate the root cause of the problem. DTCs may be erased with the scan tool.

A scan tool data display may be useful when diagnosing HEV and EHPS systems especially when there is a system problem with no DTCs. Before using the data display, the diagnostic system check should be performed and all DTCs corrected. Available scan tool data from a HEV with EHPS is illustrated in Figure 10-39. Photo Sequence 18 illustrates the safety precautions that must be observed when working on hybrid vehicles.

Scan Tool Parameter	Data List	Units Displayed	Typical Data Value
Park brake set with the ignition switch ON/Ignition Switch in RUN/Automatic Transmission in PARK/Air Conditioning is OFF			
Brake Pedal Travel	Data	mm	−50 to 200 mm
BPP Sensor Rate	Data	ms	0 to +10%/25ms
BPP Sensor Input Volts	Data	Volts	0 to 5 Volts
BPP Sensor Output Volts	Data	Volts	0 to 5 Volts
EHPS 42 V Bus Voltage	Data	Volts	0 to 76 Volts
EHPS Ignition 0	Data	OFF/ON	ON
EHPS Ignition 1	Data	OFF/ON	ON
EHPS Demand	Data	%	−100 to +100%
EHPS Demand Speed	Data	RPM	0 to +7500 RPM
EHPS ECU Temperature	Data	°C	−180 to +180°C (−238 to +302°F)
EHPS Manifold Temperature	Data	°C	−180 to +180°C (−238 to +302°F)
EHPS Motor Current	Data	A	0 to +200A
EHPS Motor RPM	Data	RPM	0 to +7500 RPM
Steering Wheel Rate	Data	°/s	0 to 2048°/s
Steering Wheel Sensor Phase A Volts	Data	Low/High	Low
Steering Wheel Sensor Phase B Volts	Data	Low/High	High
Vehicle Speed	Data	km/h	0

FIGURE 10-39 **EHPS data**

Observing Safety Precautions When Servicing Hybrid Electric Vehicles (HEVs)

P18-1 **Always wear high-voltage lineman's gloves when servicing HEV electrical systems.**

P18-2 **Periodically inspect the high-voltage gloves for pin holes or damage.**

P18-3 **Shut off the high-voltage circuit switch to isolate the battery pack from the electrical system.**

P18-4 **Disconnect the negative cable on the 12-V battery.**

P18-5 **After the high- and low-voltage systems are disabled, wait for the time specified by the vehicle manufacturer to allow these systems to completely power down.**

P18-6 **Inspect the high-voltage (orange) cables for frayed insulation and damage.**

P18-7 **If the HEV is not driven for a few weeks, the engine should be started and run for 30 minutes every 2 weeks to maintain the state of charge in the high-voltage battery pack.**

P18-8 **Always remove the electronic or conventional key from the instrument panel to prevent the engine from starting when working on an HEV electrical system.**

Terms to Know

Belt tension gauge
Crocus cloth
Flow control valve
Integral reservoir
Pressure gauge
Pressure relief valve
Remote reservoir
Ribbed V-belt
Steering effort
Serpentine belt
V-type belt
Woodruff key

CASE STUDY

The owner of a Dodge Magnum with a 5.7 L turbo-charged engine requested a price on a power steering gear replacement. The service writer questioned the owner regarding the reason for the steering gear replacement, and discovered that the problem was inter mi t-tent hard steering. Further discussion with the owner also revealed that the car had been taken to another automotive service center, and the owner was informed that her car required a steering gear replacement. The owner was now looking for a second opinion.

The technician road tested the vehicle and found no indication of hard steering. The owner was asked about the exact driving conditions when the hard steering was experienced, and the answer to this question provided the solution to the problem. The owner indicated that the hard steering was usually experienced while cornering and always on a rainy day. Once this information was revealed, the technician suspected a problem with the power steering belt, because a wet belt slips more easily. A check of the power steering belt indicated the belt was oil soaked from engine oil leaks and was also slightly loose. The power steering belt was replaced and adjusted, and the owner was informed that the engine oil leaks should be corrected or the belt would become oil soaked again.

A short while later, after a rain, the owner brought the car to the shop to have the engine oil leaks repaired. The owner reported that the belt corrected the hard steering problem. In this situation, a brief discussion about the customer's complaint led to accurate diagnosis of the problem, and because of this accurate diagnosis, the shop gained a steady customer.

ASE-Style Review Questions

1. While discussing power steering belt adjustment:
   Technician A says the tension on a power steering pump V-belt should be checked with a tension gauge.
   Technician B says that some ribbed V-belts have an automatic tensioning pulley that eliminates the need for tension adjustments.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While discussing power steering belt adjustment:
   Technician A says that a power steering pump V-belt should be tightened with a pry bar installed against the pump reservoir.
   Technician B says a loose power steering pump V-belt may cause the steering wheel to jerk while turning.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. In a hybrid electric vehicle (HEV) electrical system with a electrohydraulic power steering system (EHPS), a diagnostic trouble code (DTC) with U prefix represents a fault in the:
   A. EHPS module.
   B. Powertrain control module (PCM).
   C. Inverter.
   D. Vehicle network.

4. While discussing the steering pump pressure test:
   Technician A says the pressure gauge and valve should be connected in the power steering pump return hose to check pump pressure.
   Technician B says the pressure gauge valve should be closed for 30 seconds during the power steering pump pressure test.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

5. While discussing power steering system draining, flushing, refilling, and bleeding:
   Technician A says the return hose from the remote reservoir should be disconnected at the remote reservoir to drain the fluid.
   Technician B says the return hose should be loosened at the remote reservoir with the engine running to bleed air from the power steering system.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

6. A vehicle experiences excessive, erratic steering effort. The most likely cause of this problem is:
   A. Underinflated and worn front tires.
   B. Power steering pump V-belt pump bottomed in the pulley.
   C. Worn power steering pump mountings.
   D. Continual low power steering pump pressure.
7. A power steering system has the specified pressure with the pressure gauge valve closed or with the pressure gauge valve open and the engine running at 1,000 and 3,000 rpm. The power steering pump pressure is lower than specified with the front wheels turned fully in either direction. The cause of this problem could be:
   A. A defective steering gear.
   B. A stuck flow control valve.
   C. A stuck pressure relief valve.
   D. Worn pump vanes and cam ring.
8. All of these statements about power steering pump pulley replacement are true EXCEPT:
   A. If the pulley is retained with a nut, a woodruff key prevents pulley rotation on the shaft.
   B. If the pulley is pressed onto the shaft, a special puller must be used to remove the pulley.
   C. If the pulley is pressed onto the shaft, a soft hammer may be used to drive the pulley onto the shaft when reinstalling the pulley.
   D. If the pulley is misaligned with the engine running, the power steering pump mountings may be worn.
9. A power steering pump has the specified pressure with the pressure gauge valve closed. However, with this valve open, the pump does not have the specified pressure difference between the pressure readings at 1,000 and 3,000 rpm. The cause of this problem could be:
   A. A sticking pressure relief valve.
   B. A sticking flow control valve.
   C. A slipping pump belt.
   D. A misaligned pump pulley.
10. All of these statements about HEV service precautions are true EXCEPT:
   A. Open the high-voltage switch to isolate the high-voltage battery pack.
   B. High-voltage gloves must be worn when servicing HEV electrical systems.
   C. If the vehicle is not being driven, the high-voltage battery pack must be vented manually.
   D. Remove the electronic or conventional key from the instrument panel.

ASE Challenge Questions

1. A vehicle has intermittent excessive steering effort.

   Technician A says inspect the fluid because it probably has air in it.

   Technician B says inspect the belt because it is probably slipping.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While discussing power steering pump leaks:

   Technician A says leaks at the driveshaft seal will leave a wet and oily pump pulley backside.

   Technician B says leaks at the driveshaft seal may leave oil on the hood pad above the pump.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. A vehicle has continual excessive steering effort, but there is no noise and the fluid level in the reservoir is correct.

   Technician A says the cause of the problem could be a stuck flow control valve.

   Technician B says the cause of the problem could be air in the power steering fluid.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. There is air in the power steering fluid. To correct this problem, you should:
   A. With the engine running, crack the pressure line at the pump to release trapped air.
   B. With the engine running, turn the steering wheel full left and right.
   C. With the engine running, drain all fluid from the system and refill.
   D. With the engine stopped, raise wheels and remove the return hose from the gear. Turn the steering wheel full left and right. Refill the reservoir and replace the return hose.

5. All of the following are true EXCEPT:
   A. A loose belt may cause the steering wheel to jerk.
   B. If V-belt edges are worn, the belt may be stretched or the wrong width.
   C. An oil-soaked V-belt may slip only in wet weather.
   D. When air is in the fluid, the fluid will never reach operating temperature.

Name ______________________ Date ______________

Draining and Flushing Power Steering System

Upon completion of this job sheet, you should be able to drain and flush a power steering system.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-11: *Flush, fill, and bleed power steering systems.*

Tools and Materials

Drain pan
Specified type of power steering fluid
Floor jack
Safety stands

Describe the Vehicle Being Worked On:

Year ________ Make ______________ Model ______________________

VIN ______________________ Engine type and size ________________

Procedure

Task Completed

1. Describe the steering problems and noises that occur when there is air in the power steering system.
   ____
   ____
   ____
   ____
2. Lift the front of the vehicle with a floor jack and install safety stands under the suspension. Lower the vehicle onto the safety stands, and remove the floor jack. ☐
3. Remove the return hose from the remote reservoir that is connected to the steering gear. Place a plug on the reservoir outlet and position the return hose in an empty drain pan. ☐
4. With the engine idling, turn the steering wheel fully in each direction and stop the engine. ☐
5. Fill the reservoir to the hot full mark with the manufacturer's recommended fluid.

   Specified type of power steering fluid ______________________

   Power steering reservoir filled to the specified level with the proper power steering fluid? ☐ Yes ☐ No

   Instructor check ______________________________

Task Completed

☐ 6. Start the engine, and run the engine at 1,000 rpm while observing the return hose in the drain pan. When fluid begins to discharge from the return hose, shut the engine off.

7. Repeat steps 4, 5, and 6 until there is no air in the fluid discharging from the return hose.

Have steps 4, 5, and 6 been repeated? ☐ Yes ☐ No

Instructor check ______________________________

8. Remove the plug from the reservoir and reconnect the return hose.

Is the return hose connected and tightened? ☐ Yes ☐ No

Instructor check ______________________________

☐ 9. Fill the power steering pump reservoir to the specified level.

10. With the engine running at 1,000 rpm, turn the steering wheel fully in each direction three or four times. Each time the steering wheel is turned fully to the right or left, hold it there for 2 to 3 seconds before turning it in the other direction.

Number of times the steering wheel was turned fully in each direction ______________

11. Check for foaming of the fluid in the reservoir. When foaming is present, repeat steps 8 and 9.

Is foaming present in the power steering pump reservoir? ☐ Yes ☐ No

Have steps 8 and 9 been repeated? ☐ Yes ☐ No

Instructor check ______________________________

☐ 12. Check the fluid level and be sure it is at the hot full mark.

☐ 13. Raise vehicle with a floor jack, remove safety stands, and lower vehicle.

14. Explain how you know that all the air has been bled from the power steering system.

____

____

____

____

Instructor's Response ______________________________

____

____

Name ______________________ Date ______________

Testing Power Steering Pump Pressure

Upon completion of this job sheet, you should be able to test power steering pump pressure.

Tools and Materials

Specified type of power steering fluid
Power steering pressure test gauge
Thermometer

Describe the vehicle Being Worked On:

Year ________ Make ______________ Model ____________________
VIN ______________________ Engine type and size ________________

Procedure

Task Completed

1. With the engine stopped, disconnect the pressure line from the power steering pump. ☐
2. Connect the gauge side of the pressure gauge to the pump outlet fitting. Connect the valve side of the gauge to the pressure line. ☐

   Is the power steering pressure gauge properly connected? ☐ Yes ☐ No

   Are all power steering gauge fittings tightened to the specified torque? ☐ Yes ☐ No
3. Start the engine and turn the steering wheel fully in each direction two or three times to bleed air from the system. ☐
4. Install a thermometer in the pump reservoir fluid to measure the fluid temperature. Be sure the fluid level is correct and the fluid temperature is at least 176°F (80°C).

   Is the power steering fluid at the specified level? ☐ Yes ☐ No

   Is the power steering fluid at the proper temperature? ☐ Yes ☐ No

   Instructor check ______________________________

WARNING: During the power steering pump pressure test with the engine idling, close the pressure gauge valve for no more than 10 seconds because excessive pump pressure may cause power steering hoses to rupture, resulting in personal injury.

WARNING: Do not allow the fluid to become too hot during the power steering pump pressure test. Excessively high fluid temperature reduces pump pressure. Wear protective gloves, and always shut the engine off before disconnecting gauge fittings, because the hot fluid may cause burns.

5. With the engine idling, close the pressure gauge valve for no more than 10 seconds, and observe the pressure gauge reading. Turn the pressure gauge valve to the fully open position. If the pressure gauge reading does not equal the vehicle manufacturer's specifications, repair or replace the power steering pump.

   Specified power steering pump pressure with pressure gauge valve closed ____________

   Actual power steering pump pressure with the pressure gauge valve closed ___________

   Recommended power steering pump service.

   ____

6. Check the power steering pump pressure with the engine running at 1,000 rpm and 3,000 rpm. Record the pressure difference between the two readings.

   Specified power steering pump pressure at 1,000 rpm ______________________________

   Specified power steering pump pressure at 3,000 rpm ______________________________

   Actual power steering pump pressure at 1,000 rpm ________________________________

   Actual power steering pump pressure at 3,000 rpm ________________________________

   Recommended power steering pump service. _____________________________________

   ____

7. With the engine running, turn the steering wheel fully in one direction. Observe the steering pump pressure while holding the steering wheel in this position.

   Specified power steering pump pressure with the steering wheel turned fully in one direction __________________

   Actual power steering pump pressure with the steering wheel turned fully in one direction __________________

   Recommended power steering service.

   ____

8. Be sure the front tire pressure is correct, and center the steering wheel with the engine idling. Connect a spring scale to the steering wheel, and measure the steering effort in both directions.

   Specified force required to turn the steering wheel to the right _______________________

   Specified force required to turn the steering wheel to the left ________________________

   Actual force required to turn the steering wheel to the right _________________________

   Actual force required to turn the steering wheel to the left __________________________

   List all the required power steering service and explain the reasons why this service is necessary.

   ____

   ____

   ____

Instructor's Response ______________________________

____

____

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Name ________________________________ Date ____________________

Measure and Adjust Power Steering Belt Tension and Alignment

Upon completion of this job sheet, you should be able to measure and adjust power steering belt tension and alignment.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-13: Remove, inspect, replace and adjust power steering pump belt.

Tools and Materials

Belt tension gauge

Pry bar

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ____________________________

VIN ______________________________ Engine type and size ____________________

Procedure

Task Completed

1. Describe the power steering problems and noises that occur when the power steering pump belt is loose.

____

____

____

____

2. Inspect the power steering belt for fraying, oil soaking, wear on friction surfaces, cracks, glazing, and splits. ☐

   Belt condition: ☐ Satisfactory ☐ Unsatisfactory

3. With the engine stopped, press on the belt at the longest belt span to measure the belt deflection which should be 1/2 inch per foot of free span. ☐

   Length of belt span where belt deflection is measured ________________________

   Amount of belt deflection ________________________

   Belt tension: ☐ Satisfactory ☐ Unsatisfactory

4. Install a belt tension gauge over the belt in the center of the longest span to measure the belt tension.

   Specified belt tension ________________________

   Actual belt tension ________________________

Task Completed

☐ **5.** Loosen the power steering pump bracket or tension adjusting bolt.

☐ **6.** Loosen the power steering pump mounting bolts.

☐ **7.** Remove the power steering belt.

☐ **8.** Check the bracket and pump mounting bolts for wear.

Power steering pump mounting bolt holes and bolt condition:
☐ Satisfactory ☐ Unsatisfactory

Power steering pump bracket and bracket bolt condition:
☐ Satisfactory ☐ Unsatisfactory

List the required power steering pump and bracket service and explain the reasons for your diagnosis.

____

____

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☐ **9.** Install the new power steering pump belt over all the pulleys.

☐ **10.** Pry against the pump ear and hub with a pry bar to tighten the belt. Some pump brackets have a 1/2-inch square opening in which a breaker bar may be installed to move the pump and tighten the belt.

☐ **11.** Hold the pump in the position described in step 9 and tighten the bracket or tension adjusting bolt.

12. Recheck the belt tension with the tension gauge.

Specified power steering belt tension ______________________

Actual power steering pump belt tension ______________________

13. Tighten the tension adjusting bolt and the mounting bolts to the manufacturer's specified torque.

Specified power steering pump mounting bolt torque ______________

Actual power steering pump mounting bolt torque ______________

Specified power steering pump bracket or tension adjusting bolt torque ________

Actual power steering pump bracket or tension adjusting bolt torque ________

14. Check alignment of the power steering pump pulley in relation to the other pulleys surrounded by the power steering belt.

Power steering pump pulley alignment: ☐ Satisfactory ☐ Unsatisfactory

Explain the service required to align the power steering pump pulley with other related pulleys and give the reasons for your diagnosis.

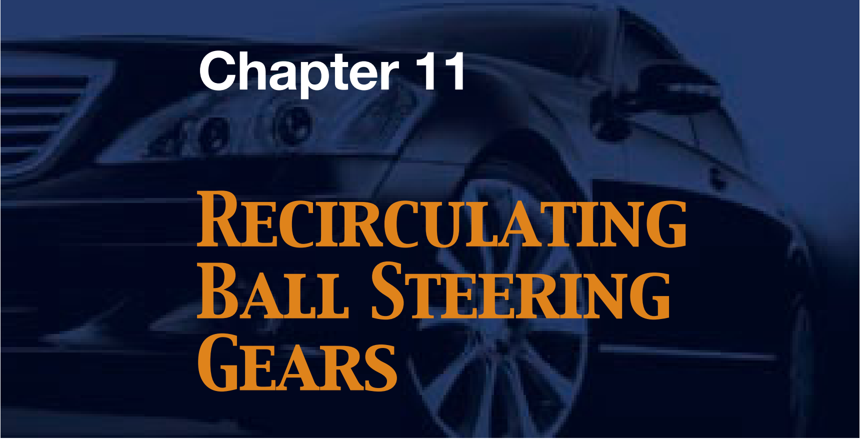
____

____

Instructor's Response ______________________________________

____

____



Chapter 11

Recirculating Ball Steering Gears

Upon completion and review of this chapter, you should be able to understand and describe:

- The purpose of a steering gear.
- The advantage of a recirculating ball steering gear compared with earlier worm and roller or cam and lever steering gears.
- The purpose of the worm shaft preload adjustment.
- How the sector shaft is rotated in a manual recirculating ball steering gear.
- The purpose of the interference fit between the sector shaft teeth and the recirculating ball teeth, and explain how this fit is obtained.
- The difference between constant ratio sector teeth and variable ratio sector teeth in a recirculating ball steering gear, and explain the advantage of the variable ratio sector teeth.
- Gear ratio.
- The term "faster" steering as it relates to steering gears.
- The power steering fluid movement in a power recirculating ball steering gear with the engine running and the front wheels straight ahead.
- The power steering fluid movement in a power recirculating ball steering gear during a left turn.
- The power steering fluid movement during a right turn.
- How kickback action is prevented in a power recirculating ball steering gear.

Introduction

The purpose of the steering gear box is to provide a mechanical advantage that allows the driver to turn the front wheels with a reasonable amount of effort. In the early 1900s, steering gears were a **worm and gear** or **worm and sector design**. These steering gears gave the driver a mechanical advantage to turn the front wheels, but they created a lot of friction.

The **Ross cam and lever steering gear** was introduced in 1923. The cam in this gear was a spiral groove machined into the end of the steering shaft. A pin on the pitman shaft was mounted in the spiral groove in the steering shaft. When the steering wheel and shaft were turned, the pin was forced to move, and this action rotated the pitman shaft. When a front wheel struck a road irregularity, this steering gear design prevented serious **kickback** on the steering wheel. However, this steering gear design still created a considerable amount of friction and required higher steering effort.

In the mid-1920s, Saginaw Steering Division of General Motors Corporation developed the **worm and roller steering gear**. In this steering gear, the **sector** became a roller, which greatly reduced friction and steering effort. The Saginaw worm and roller steering gear was

A Bit of History

Steering gear design progressed from the crude, high-friction worm and gear of the early 1900s to the Ross cam and lever gear and Saginaw worm and roller gear of the 1920s. The Saginaw worm and roller steering gear was the forerunner of the modern, low-friction recirculating ball steering gear.

In a **worm and gear** or **worm and sector design**, the sector teeth are in direct contact with the worm.

Steering **kickback** refers to a strong and sudden movement of the steering wheel in the opposite direction to which the steering wheel is turned. This kickback action tends to occur if a front wheel strikes a road irregularity during a turn.

the forerunner of the recirculating ball steering gear that has been widely used on rear-wheel-drive cars for many years.

Manual Recirculating Ball Steering Gears

Design and Operation

In a recirculating ball steering gear, the steering wheel and shaft are connected to the **worm shaft**. Ball bearings support both ends of the worm shaft in the steering gear housing. A seal above the upper worm shaft bearing prevents oil leaks, and an adjusting plug is provided on the upper worm shaft bearing to adjust **worm shaft bearing preload**. Proper preloading of the worm shaft bearing is necessary to eliminate **worm shaft endplay** and to prevent **steering gear free play** and **vehicle wander**. A ball nut is mounted over the worm shaft, and internal threads or grooves on the ball nut match the grooves on the worm shaft. Ball bearings run in ball nut and worm shaft grooves (Figure 11-1).

When the worm shaft is rotated by the steering wheel, the ball nut is moved up or down on the worm shaft. The gear teeth on the ball nut are meshed with matching gear teeth on the **pitman shaft sector**. Therefore, ball nut movement causes pitman shaft sector rotation. Since the pitman shaft sector is connected through the pitman arm and steering linkage to the front wheels, the front wheels are turned by the pitman shaft sector. The lower end of the

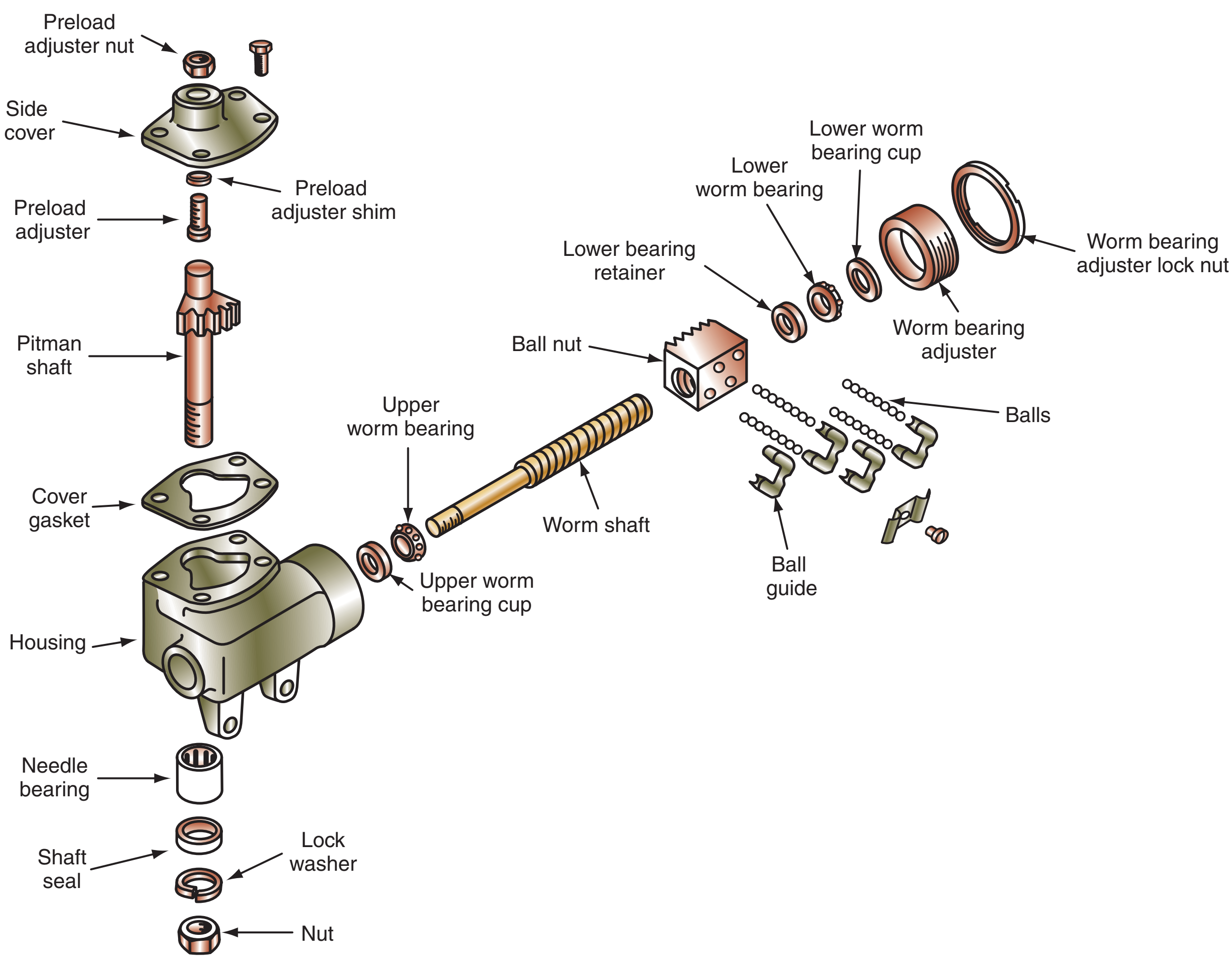


FIGURE 11-1 **Manual recirculating ball steering gear design.**

pitman shaft sector is usually supported by a bushing or a needle bearing in the steering gear housing. A bushing in the side cover supports the upper end of this shaft.

When the front wheels are straight ahead, an **interference fit** exists between the sector shaft teeth and ball nut teeth. This interference fit eliminates **gear tooth backlash** when the front wheels are straight ahead and provides the driver with a positive feel of the road. Proper axial adjustment of the sector shaft is necessary to obtain the necessary interference fit between the sector shaft and worm shaft teeth. A sector shaft adjuster screw is threaded into the side cover to provide axial sector shaft adjustment (Figure 11-2).

Manual recirculating ball steering gears have sector gear teeth designed to provide a constant ratio, whereas power recirculating ball steering gears usually have sector gear teeth with a variable ratio (Figure 11-3). The sector gear teeth have equal lengths in a constant ratio steering gear, but the center sector gear tooth is longer compared with the other teeth in a variable ratio gear. The variable ratio steering gear varies the amount of mechanical advantage provided by the steering gear in relation to steering wheel position. This variable ratio provides **faster steering**. The steering **gear ratio** in a constant ratio manual steering gear is usually 15:1 or 16:1, whereas the average variable ratio steering gear ratio may be 13:1. When the same types of steering gears are compared, a higher numerical ratio provides reduced steering effort and increased steering wheel movement in relation to the amount of front wheel movement.

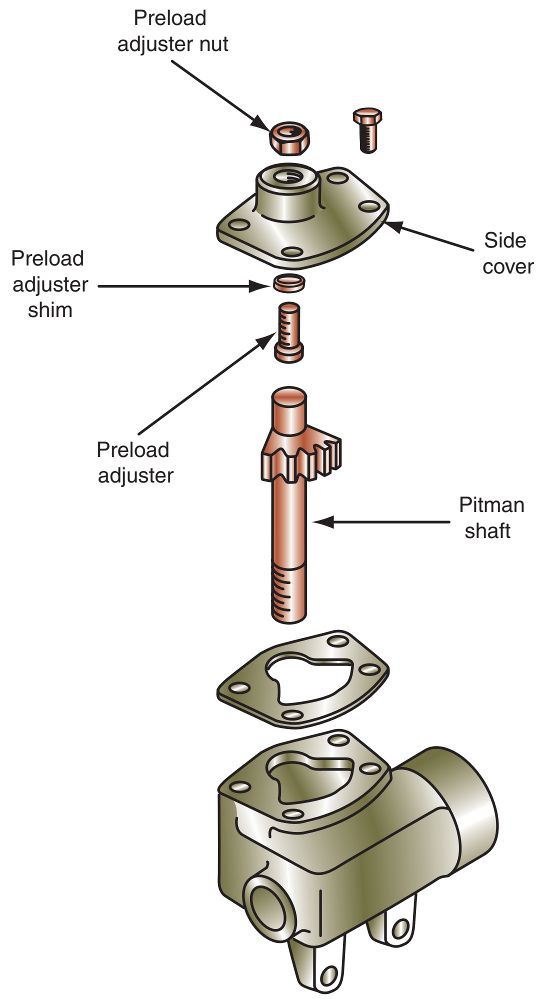


FIGURE 11-2 **Sector shaft adjusting nut.**

A **sector** may be defined as part of a gear.

The **worm shaft** is a spiral gear connected through the steering shaft to the steering wheel.

Worm shaft bearing preload is a condition where all endplay is removed and there is a slight tension placed on the bearing.

Worm shaft endplay refers to movement of this shaft between the bearings on which the shaft is mounted.

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Steering gear free play refers to the amount of steering wheel rotation before the front wheels begin to turn right or left.

Vehicle wander is the tendency of a vehicle to steer to the right or left as it is driven straight ahead.

The **pitman shaft sector** is meshed with the ball nut teeth.

Gear tooth backlash refers to movement between gear teeth that are meshed with each other.

A steering gear with a lower numerical ratio may be called a **faster steering** gear compared with a steering gear with a higher numerical ratio.

Gear ratio refers to the relationship between the rotation of the drive and driven gears. If 13 turns of the drive gear are necessary to obtain one turn of the driven gear, the gear ratio is 13:1.

CAUTION: Hard steel bolts can be used for steering gear mounting. Bolt hardness is indicated by the number of ribs on the bolt head. Harder bolts have five, six, or seven ribs on the bolt heads. Never substitute softer steel bolts in place of the original harder bolts, because these softer bolts may break, allowing the steering gear box to detach from the frame. This action results in a loss of steering control.

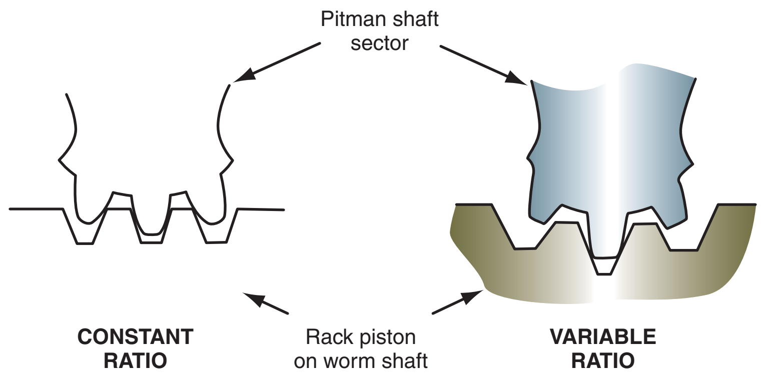

FIGURE 11-3 **Constant and variable ratio steering gears.**

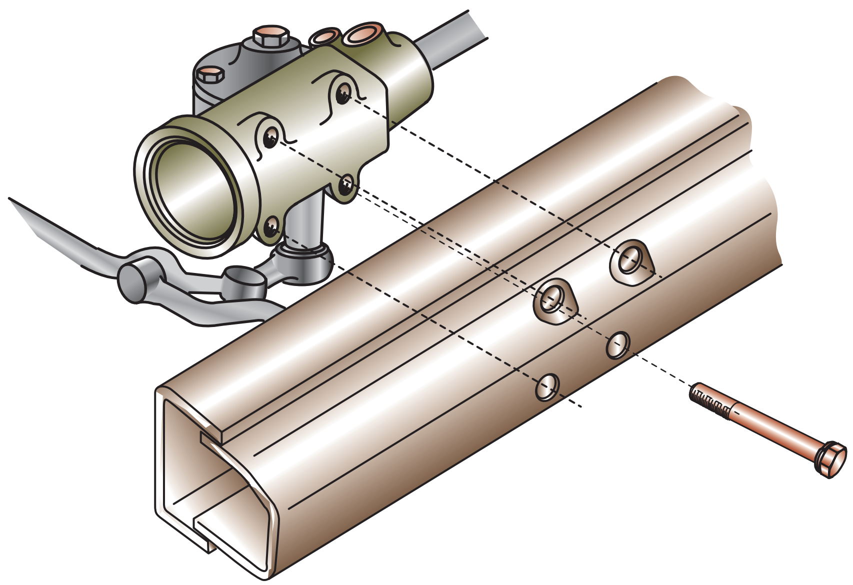

FIGURE 11-4 **Steering gear mounting on the vehicle frame.**

Many recirculating ball steering gears are bolted to the frame with hard steel bolts (Figure 11-4). These bolts must be tightened to the vehicle manufacturer's specified torque.

Power Recirculating Ball Steering Gears

Design and Operation

The ball nut and pitman shaft sector are similar in manual and power recirculating ball steering gears. In the power steering gear, a **torsion bar** is connected between the steering shaft and the worm shaft. Since the front wheels are resting on the road surface, they resist turning, and the parts attached to the worm shaft also resist turning. This turning resistance causes torsion bar twist when the wheels are turned, and this twist is limited to a predetermined amount. The worm shaft is connected to the **rotary valve** body, and the torsion bar pin also connects the torsion bar to the worm shaft. The upper end of the torsion bar is attached to the steering shaft and wheel. A stub shaft is mounted inside the rotary valve and a pin connects the outer end of this shaft to the torsion bar. The pin on the inner end of the stub shaft is connected to the **spool valve** in the center of the rotary valve (Figure 11-5).

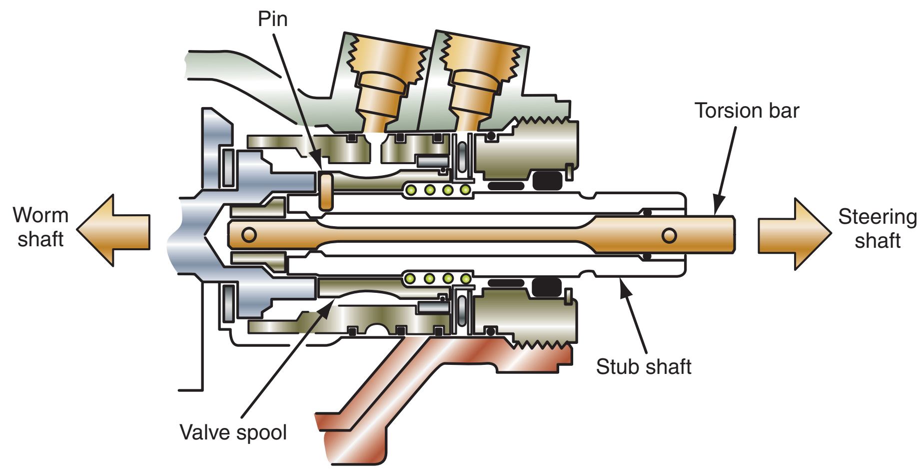

FIGURE 11-5 **Torsion bar and stub shaft.**

WARNING: Many recirculating ball steering gears are mounted near the exhaust manifold, which can be extremely hot. Use caution and wear protective gloves when inspecting or servicing the steering gear to avoid burns to hands and arms.

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When the car is driven with the front wheels straight ahead, oil flows from the power steering pump through the spool valve, rotary valve, and low-pressure return line to the pump inlet (Figure 11-6). In the straight-ahead steering gear position, oil pressure is equal on both sides of the recirculating ball piston, and the oil acts as a cushion that prevents road shocks from reaching the steering wheel.

If the driver makes a left turn, torsion bar twist moves the valve spool inside the rotary valve body so that oil flow is directed through the rotary valve to the left-turn holes in the

The **rotary valve** is mounted over the top of the spool valve in a steering gear.

The **spool valve** is mounted inside the rotary valve. The twisting action of the torsion bar moves the spool valve in relation to the rotary valve.

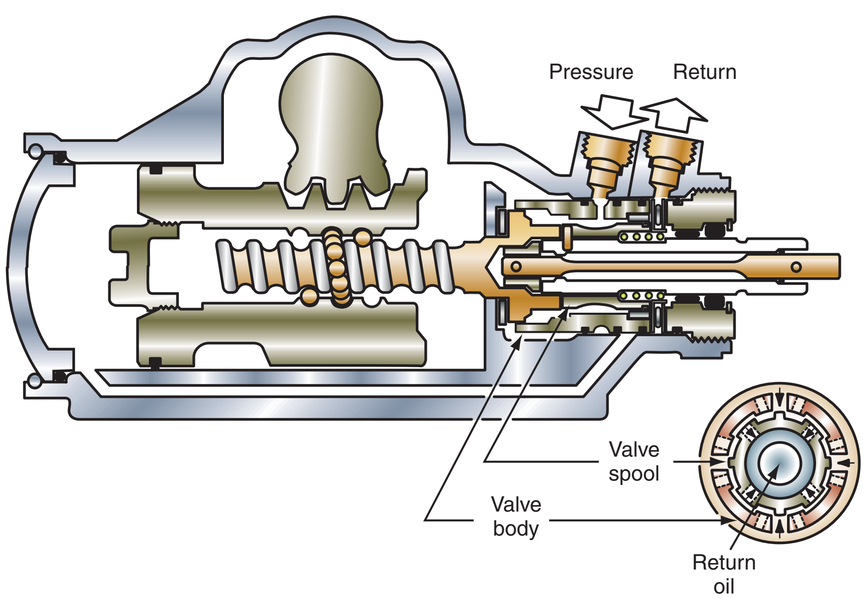

FIGURE 11-6 **Power steering gear fluid flow with the wheels straight ahead.**

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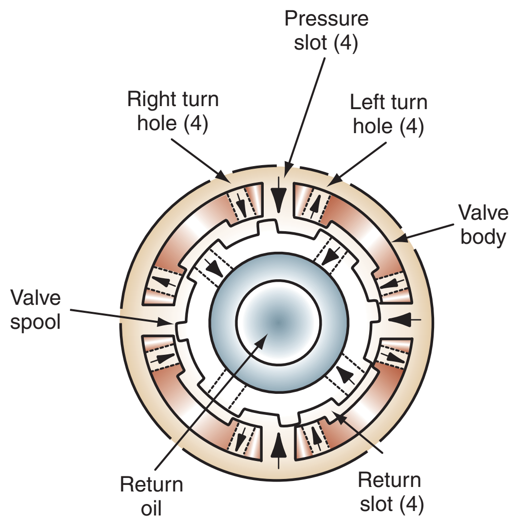


FIGURE 11-7 **Spool valve position during a left turn.**

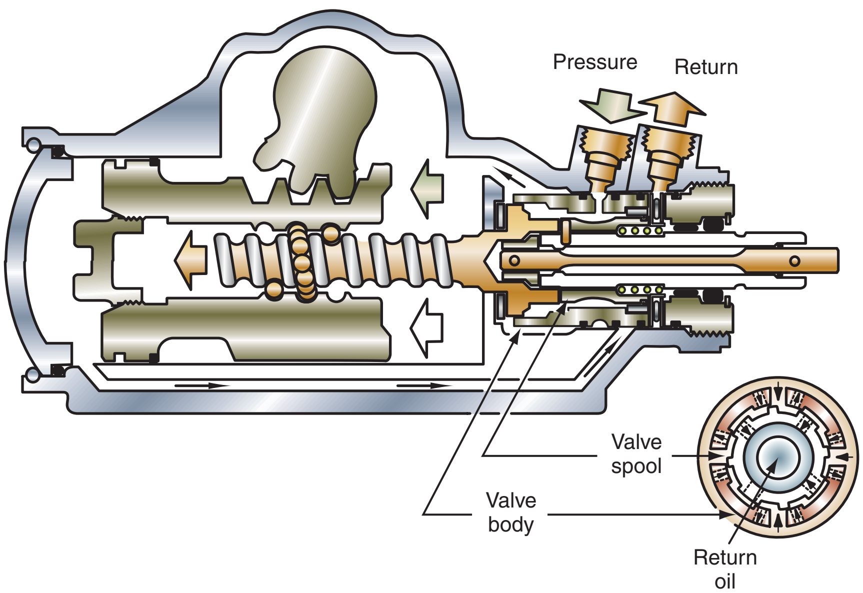


FIGURE 11-8 **Power steering gear fluid flow during a left turn.**

spool valve (Figure 11-7). Since power steering fluid is directed from these left-turn holes to the upper side of the recirculating ball piston (Figure 11-8), this hydraulic pressure on the piston assists the driver in turning the wheels to the left.

When the driver makes a right turn, torsion bar twist moves the spool valve so that oil flows through the spool valve, rotary valve, and a passage in the housing to the pressure chamber at the lower end of the ball nut piston (Figure 11-9). During a right turn, hydraulic pressure applied to the lower end of the recirculating ball piston helps the driver turn the wheels.

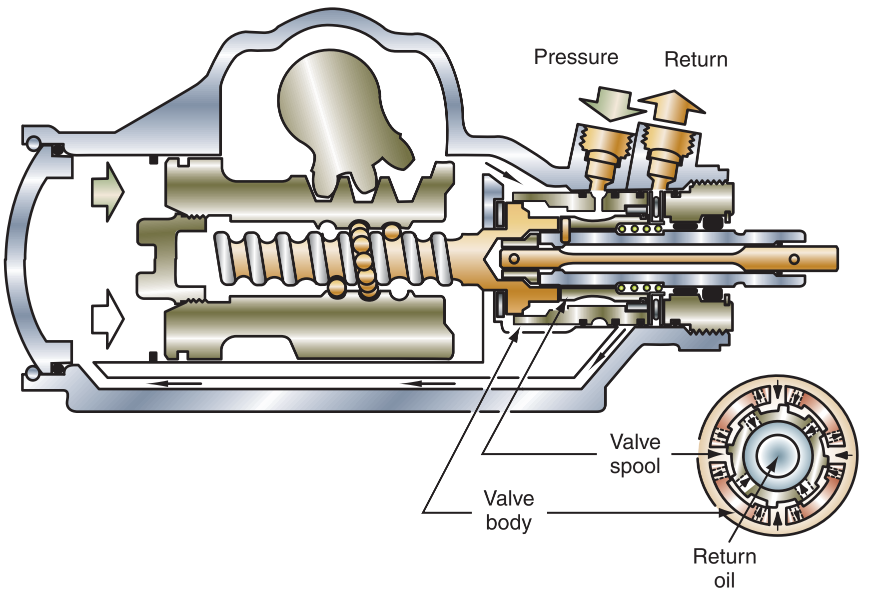


FIGURE 11-9 **Power steering gear fluid flow during a right turn.**

During a turn, if a front wheel strikes a bump and the front wheels are driven in the direction opposite the turning direction, the recirculating ball piston tends to move against the hydraulic pressure and force oil back out the pressure inlet port. This action would create a kickback on the steering wheel, but a poppet valve in the pressure inlet fitting closes and prevents kickback action.

AUTHOR'S NOTE: After road testing many vehicles to diagnose steering problems, it has been my experience that the rack and pinion steering gear and related linkage tends to transfer more road shock from the front wheels to the steering wheel compared with a recirculating ball steering gear. The design of the recirculating ball steering gear and the related steering linkage resists the transfer of road shock from the front wheels to the steering wheel. The reason for this resistance is the linkage design in which the steering arms are connected through the tie-rods to the center link, and this link is connected through the pitman arm to the steering gear. In a rack and pinion steering gear, the tie-rods are connected directly between the steering arms and the rack, and the rack is connected through the pinion to the steering wheel. Compared with a recirculating ball steering gear, a rack and pinion steering gear with its related linkage has fewer friction points and a more direct connection between the front wheels and the steering wheel. However, the rack and pinion steering gear does provide the driver with a greater feel of the road.

You need to be aware of the characteristics of these steering systems when diagnosing steering problems. When you understand the basic characteristics of these steering systems, you are able to immediately recognize normal and abnormal conditions, and this allows you to provide a fast, accurate diagnosis.

Terms to Know

Faster steering
Gear ratio
Gear tooth backlash
Interference fit
Kickback
Pitman shaft sector
Ross cam and lever steering gear
Rotary valve
Sector
Spool valve
Steering gear free play
Torsion bar
Vehicle wander
Worm and gear
Worm and roller steering gear
Worm and sector design
Worm shaft
Worm shaft bearing preload
Worm shaft endplay

Summary

- Early model steering gears such as the worm and gear or Ross cam and lever created a lot of friction and required higher steering effort.
- The modern recirculating ball steering gear reduces friction and steering effort.
- In a manual recirculating ball steering gear, a worm shaft adjusting plug provides a worm shaft preload adjustment.
- In a recirculating ball steering gear, rotation of the steering wheel causes the ball nut to move up and down on the worm shaft.
- With the front wheels straight ahead in a recirculating ball steering gear, an interference fit exists between the ball nut teeth and the sector shaft teeth.
- Axial sector shaft adjustment provides the proper interference fit between the ball nut teeth and the sector shaft teeth.
- Sector shaft teeth may have a constant ratio design or a variable ratio design.
- In a power recirculating ball steering gear with the front wheels straight ahead, equal pressure is applied to both sides of the recirculating ball piston, and the fluid from the pump is directed through the spool valve and rotary valve to the return hose and pump inlet.
- In a power recirculating ball steering gear, the spool valve movement inside the rotary valve is controlled by torsion bar twist.
- When the front wheels are turned in a power recirculating ball steering gear, torsion bar twist moves the spool valve inside the rotary valve, and this valve movement directs the power steering fluid to the appropriate side of the recirculating ball piston to assist steering.

Review Questions

Short Answer Essays

1. Describe the advantage of the manual recirculating ball steering gear compared with the previous cam and lever steering gear, and explain how this advantage is obtained.
2. Explain three purposes of the worm shaft preload adjustment.
3. Explain the purpose of the interference fit between the ball nut teeth and the sector shaft teeth in a manual recirculating ball steering gear, and describe how this interference fit is obtained.
4. Explain the difference in design between constant ratio and variable ratio sector shaft teeth.
5. Define the term faster steering.
6. Define steering gear ratio, and explain the effect of this ratio on steering effort with a manual recirculating ball steering gear.
7. Describe the flow of power steering fluid with the engine running and the front wheels straight ahead in a power recirculating ball steering gear.
8. Describe how torsion bar twist occurs in a recirculating ball steering gear.
9. Explain the purpose of torsion bar twist in a power recirculating ball steering gear.
10. Explain how kickbacks are prevented in a power recirculating ball steering gear.

Fill-in-the-Blanks

1. A manual recirculating ball steering gear provides reduced _______________ and _______________ _______________compared with the earlier cam and lever manual steering gear.
2. If a bearing has preload, there is a slight ___________ on the bearing.
3. When the steering has free play, there is some _______________ _______________ movement before the front wheels start to turn.
4. The worm shaft end plug provides a worm shaft bearing _______________ adjustment.
5. In a manual recirculating ball steering gear, the interference fit between the ball nut and sector shaft teeth is obtained by proper _______________ sector shaft adjustment.
6. Compared with a constant ratio steering gear with a ratio of 13:1, a constant ratio steering gear with a ratio of 16:1 requires _______________ steering effort.
7. When a faster steering system is compared with a slower steering system, the faster system provides more front wheel movement with _______________ steering wheel rotation.
8. A variable ratio steering gear varies the amount of _______________ _______________ in relation to steering wheel position.
9. In a power recirculating ball steering gear with the front wheels straight ahead and the engine running, the fluid on each side of the recirculating ball piston helps prevent _______________ ____________ from reaching the steering wheel.
10. In a power recirculating ball steering gear during a turn, the _______________ _______________ movement directs the power steering fluid pressure to the appropriate side of the recirculating ball piston.

Multiple Choice

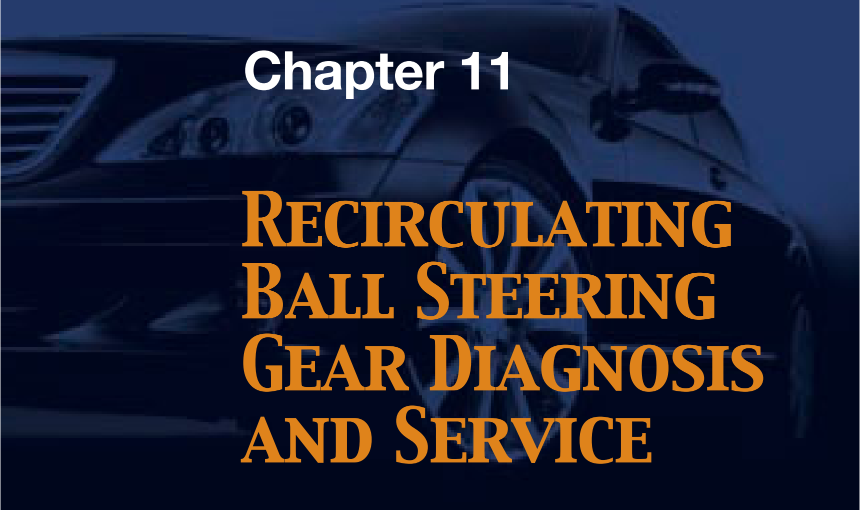
1. In a power recirculating ball steering gear, kickback is prevented by:
   A. The preload between the ball nut teeth and sector gear teeth.
   B. The bending of the torsion bar.
   C. A poppet valve in the pressure inlet fitting.
   D. The flexible coupling in the steering shaft.
2. When the worm shaft and bearings are properly installed and adjusted in a power recirculating ball steering gear:
   A. The worm shaft bearings should be preloaded.
   B. The worm shaft should have the specified end-play.
   C. The worm shaft endplay should be eliminated without any preload on the bearings.
   D. There must be an interference fit between the ball nut teeth and the worm shaft teeth.
3. All of these statements about recirculating ball steering gears are true EXCEPT:
   A. The steering gear provides a mechanical advantage.
   B. The steering gear reduces steering effort.
   C. Some early model steering gears had a worm and sector design.
   D. Ross cam and lever steering gears provided a very low internal friction.
4. A typical steering gear ratio in a manual steering gear is:
   A. 16:1.
   B. 18:1.
   C. 19:1.
   D. 22:1.
5. When comparing manual recirculating ball steering gears a higher numerical ratio provides:
   A. Increased steering effort.
   B. Increased steering wheel movement in relation to front wheel movement.
   C. Reduced kickback force on the steering wheel.
   D. Improved steering control.
6. In a manual recirculating ball steering gear:
   A. The interference fit between the sector shaft teeth and ball nut teeth is present when the front wheels are straight ahead.
   B. The proper interference fit between the sector shaft teeth and ball nut teeth is obtained by radial sector shaft movement.
   C. The interference fit between the sector shaft teeth and ball nut teeth becomes tighter when the front wheels are turned to the right or left.
   D. Tightening the worm shaft adjusting plug tightens the interference fit between the sector shaft teeth and ball nut teeth.

7. All of these statements about steering gear ratios are true EXCEPT:
   A. When a steering gear with a 15:1 ratio is compared with a steering gear with a 13:1 ratio, the gear with the 15:1 ratio requires more steering wheel rotation to turn the front wheels.
   B. When a steering gear with a 15:1 ratio is compared with a steering gear with a 13:1 ratio, the gear with the 15:1 ratio provides reduced steering effort.
   C. When a steering gear with a 15:1 ratio is compared with a steering gear with a 13:1 ratio, the gear with the 15:1 ratio may be called a faster steering gear.
   D. The 13:1 steering gear ratio may be used on a smaller, lighter car and the 15:1 steering gear ratio may be used on a larger, heavier vehicle.

8. In power recirculating ball steering gears:
   A. A variable ratio steering gear has sector shaft teeth with equal lengths.
   B. A variable ratio steering gear has a constant mechanical advantage regardless of steering wheel position.
   C. The torsion bar is connected between the steering shaft and the sector shaft.
   D. During a turn, power steering fluid is directed to the proper end of the ball nut piston by spool valve movement.

9. While driving with the front wheels straight ahead with a power recirculating ball steering gear:
   A. The torsion bar is twisted to move the spool valve inside the valve body.
   B. The fluid pressure is higher on the upper side of the ball nut piston compared with the lower side.
   C. The fluid pressure on each side of the ball nut piston cushions road shocks from reaching the steering wheel.
   D. The return passage from the steering gear valve body to the power steering pump is nearly closed.

10. When a vehicle with a power recirculating ball steering gear is making a right turn:
    A. Torsion bar twisting and spool valve movement has moved the spool valve and aligned the pressure ports with the right-turn ports.
    B. Fluid pressure is supplied to the upper side of the ball nut piston.
    C. Fluid pressure is exhausted from the lower side of the ball nut piston.
    D. Fluid pressure gradually leaks past the ball nut piston to reduce steering assist during long, gradual turns.



Chapter 11

Recirculating Ball Steering Gear Diagnosis and Service

Upon completion and review of this chapter, you should be able to:

- Diagnose power recirculating ball steering gear problems.
- Remove and replace power recirculating ball steering gears.
- Adjust worm shaft thrust bearing preload in power recirculating ball steering gears.
- Adjust sector lash in power recirculating ball steering gears.
- Diagnose and repair oil leaks in power recirculating ball steering gears.
- Disassemble, repair, and reassemble power recirculating ball steering gears.

Steering gear and linkage inspection and service is extremely important to maintain vehicle safety! For example, if a vehicle has excessive steering wheel free play, this problem should be diagnosed and corrected as soon as possible. If the excessive steering wheel free play is caused by a loose sector shaft lash or worm bearing preload adjustments, follow the proper adjustment procedure to correct the problem. However, if this problem is caused by worn tie-rod ends or loose steering gear mounting bolts, these conditions create a safety hazard. If a worn tie-rod end becomes disconnected, or the steering gear becomes disconnected from the frame, the result is a complete loss of steering control. This condition may cause a collision resulting in vehicle damage and/or personal injury.

BASIC TOOLS

Basic technician's tool set

Service manual

Power Recirculating Ball Steering Gear Diagnosis

If the steering gear is noisy, check these items:

1. Loose pitman shaft lash adjustment—may cause a rattling noise when the steering wheel is turned.
2. Cut or worn dampener O-ring on the valve spool—when this defect is present, a squawking noise is heard during a turn.
3. Loose steering gear mounting bolts.
4. Loose or worn flexible coupling or steering shaft U-joints.

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A hissing noise from the power steering gear is normal if the steering wheel is at the end of its travel, or when the steering wheel is rotated with the vehicle standing still. If the steering wheel jerks or surges when the steering wheel is turned with the engine running, check the power steering pump belt condition and tension. When excessive kickback is felt on the steering wheel, check the poppet valve in the steering gear.

When the steering is loose, check these defects:

1. Air in the power steering system. To remove the air, fill the power steering pump reservoir and rotate the steering wheel fully in each direction several times.
2. Loose pitman lash adjustment.
3. Loose worm shaft thrust bearing preload adjustment.
4. Worn flexible coupling or universal joint.
5. Loose steering gear mounting bolts.
6. Worn steering gears.

A complaint of hard steering while parking could be caused by one of these defects:

1. Loose or worn power steering pump belt.
2. Low oil level in the power steering pump.
3. Excessively tight steering gear adjustments.
4. Defective power steering pump with low-pressure output.
5. Restricted power steering hoses.
6. Defects in the steering gear such as:
   (a) Pressure loss in the cylinder because of scored cylinder, worn piston ring, or damaged backup O-ring.
   (b) Excessively loose spool in the valve body.
   (c) Defective or improperly installed gear check poppet valve.

CAUTION: Hard steel bolts can be used for steering gear mounting. Ribs on the bolt head indicate the bolt hardness. Harder bolts have five, six, or seven ribs on the bolt heads. Never substitute softer steel bolts in place of the harder original bolts, because these softer bolts may break, allowing the steering gear box to detach from the frame and resulting in a loss of steering control.

Power Recirculating Ball Steering Gear Replacement

When the power steering gear is replaced, proceed as follows:

1. Disconnect the hoses from the steering gear and cap the lines and fittings to prevent dirt from entering the system.
2. Remove the pitman arm nut and washer and mark the pitman arm in relation to the shaft with a center punch. Use a puller to remove the pitman arm.
3. Disconnect the steering shaft from the worn shaft.
4. Remove the steering gear mounting bolts and remove the steering gear from the chassis (Figure 11-1).
5. Reverse steps 1 through 4 to install the steering gear. All bolts must be tightened to the specified torque. Be sure the pitman arm is installed in the original position.

CAUTION: When the steering linkage is disconnected from the gear, do not turn the steering wheel hard against the stops. This action may damage internal steering gear components.

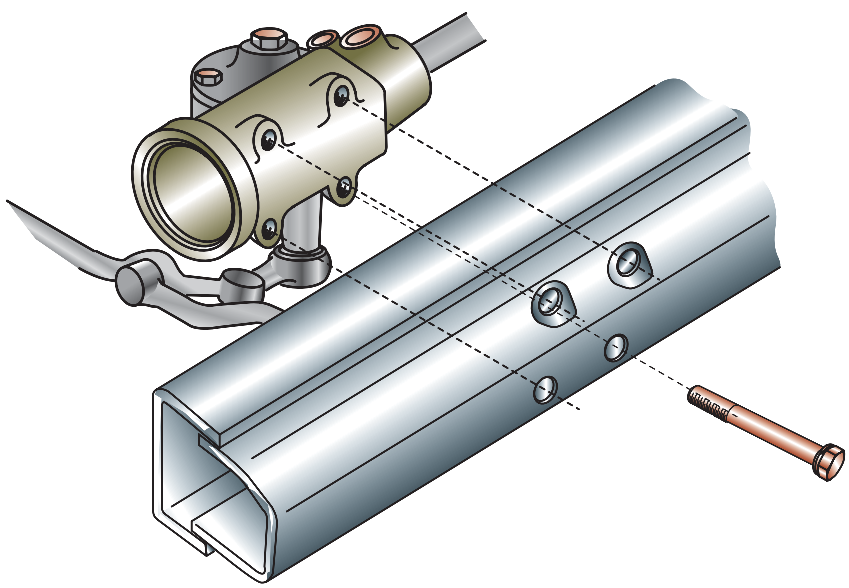

FIGURE 11-1 **Removing steering gear from the chassis.**

WARNING: The steering gear is often mounted near the exhaust system components. Wear protective gloves when working on a steering gear located near the exhaust system.

Power Recirculating Ball Steering Gear Adjustments

Worm Shaft Thrust Bearing Preload Adjustment

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Chapter 11, page 258

A loose worm shaft thrust **bearing preload** adjustment or sector lash adjustment causes excessive **steering wheel free play** and steering wander. The power recirculating ball steering gear adjustment procedures may vary depending on the vehicle make and model year. Always follow the vehicle manufacturer's recommended procedure in the service manual.

When the worm shaft thrust bearing preload adjustment is performed, use this procedure:

1. Remove the worm shaft thrust bearing adjuster plug locknut with a hammer and brass punch (Figure 11-2).
2. Turn this adjuster plug inward, or clockwise, until it bottoms, and tighten the plug to 20 ft-lb. (27 Nm).
3. Place an index mark on the steering gear housing next to one of the holes in the adjuster plug (Figure 11-3).
4. Measure 0.50 in. (13 mm) counterclockwise from the index mark, and place a second index mark at this position (Figure 11-4).
5. Rotate the adjuster plug counterclockwise until the hole in the adjuster plug is aligned with the second index mark placed on the housing (Figure 11-5).
6. Install and tighten the adjuster plug locknut to the specified torque.

Photo Sequence 19 shows a typical procedure for performing a worm shaft bearing preload adjustment.

Bearing preload is a condition when end play is removed from the bearing and slight tension is applied to the bearing.

Steering wheel free play is the amount of steering wheel movement before the front wheels begin to turn.

Pitman Sector Shaft Lash Adjustment

When the **sector shaft lash** adjustment is too loose, steering wheel free play is excessive, which causes **vehicle wander** when the vehicle is driven straight ahead. A loose sector shaft lash adjustment decreases driver **road feel**. If the sector lash adjustment is too tight, steering effort is increased, especially with the front wheels in the straight-ahead position.

SPECIAL TOOLS
Worm shaft adjuster plug rotating tool

Sector shaft lash refers to the movement between the sector teeth and ball nut teeth.

Vehicle wander is the tendency of a vehicle to steer right or left as it is driven straight ahead.

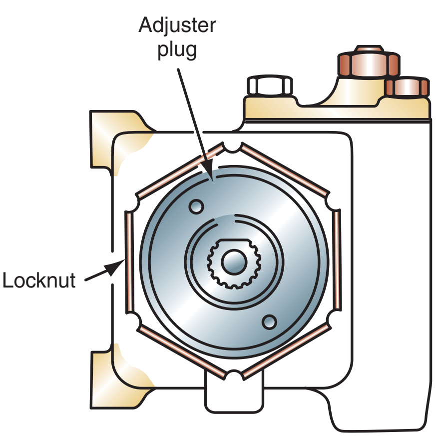


FIGURE 11-2 **Removing worm shaft thrust bearing adjuster plug locknut.**

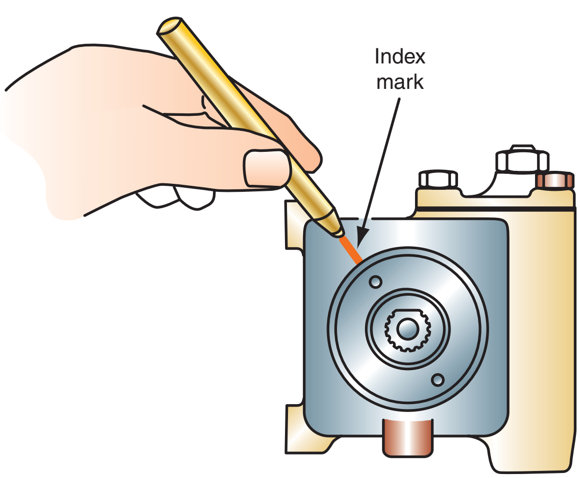


FIGURE 11-3 **Placing index mark on steering gear housing opposite one of the adjuster plug holes.**

Typical Procedure for Performing a Worm Shaft Bearing Preload Adjustment

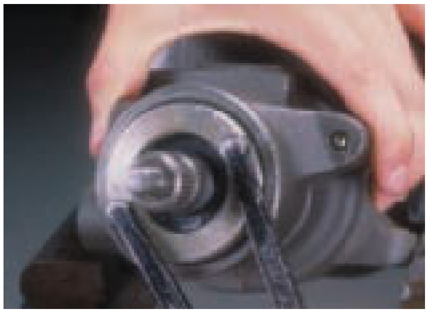
P19-1 **Retain the steering gear in a vise.**

P19-2 **Remove the worm shaft bearing locknut with a hammer and brass punch.**

P19-3 **Use the proper tool to turn the worm shaft adjuster plug clockwise until it bottoms, and tighten this plug to 20 ft-lb. (27 Nm).**

P19-4 **Place an index mark on the steering gear housing next to one of the adjuster plug holes.**

P19-5 **Measure 0.50 in. (13 mm) counterclockwise from the mark placed on the housing in step P11-4, and place a second mark on the housing.**



P19-6 **Rotate the worm shaft adjuster plug counterclockwise until the adjuster plug hole is aligned with the second mark placed on the housing.**

P19-7 **Install and tighten the worm shaft adjuster plug locknut.**

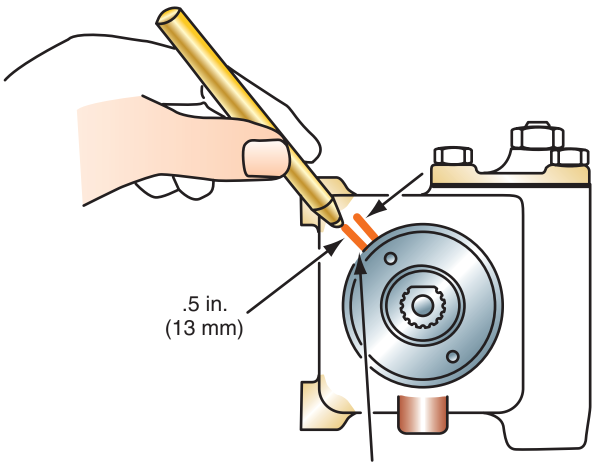


FIGURE 11-4 **Measuring 0.50 in. (13 mm) counterclockwise from the index mark on the steering gear housing.**

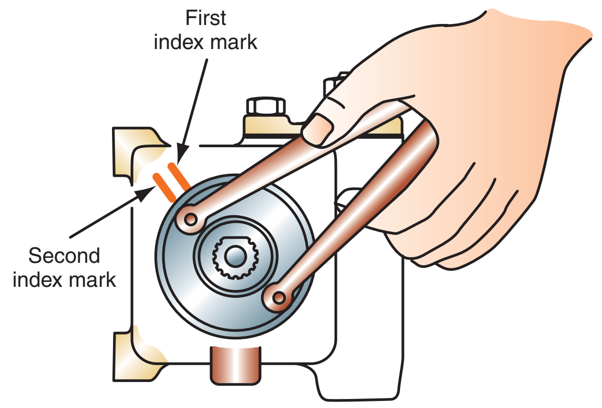


FIGURE 11-5 **Aligning adjuster plug hole with the second index mark placed on steering gear housing.**

When the pitman sector shaft lash adjustment is performed, proceed as follows:

1. Rotate the stub shaft from stop to stop and count the number of turns.
2. Starting at either stop, turn the stub shaft back one-half of the total number of turns. In this position, the flat on the stub shaft should be facing upward (Figure 11-6), and the master spline on the pitman shaft should be aligned with the pitman shaft backlash adjuster screw (Figure 11-7).
3. Loosen the locknut and turn the pitman shaft backlash adjuster screw fully counterclockwise, and then turn it clockwise one turn.
4. Use an inch-pound torque wrench to turn the stub shaft through a 45° arc on each side of the position in step 2. Read the over-center torque as the stub shaft turns through the center position (Figure 11-8).
5. Continue to adjust the pitman shaft adjuster screw until the torque is 6 to 10 in-lb. (0.6 to 1.2 Nm) more than the torque in step 4.
6. Hold the pitman shaft adjuster screw in this position, and tighten the locknut to the specified torque as illustrated in Photo Sequence 20.

Road feel is experienced by a driver when the steering wheel is turned and the driver has a positive feeling that the front wheels are turning in the intended direction.

SERVICE TIP:
When tightening the pitman backlash adjuster screw locknut, it is very important to hold the pitman arm lash adjuster screw with a screwdriver to prevent this screw from turning. If the pitman lash adjuster screw turns when the locknut is tightened, the adjustment is changed.

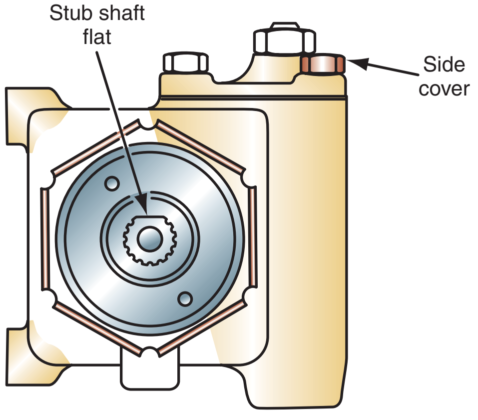


FIGURE 11-6 **Stub shaft flat facing upward and parallel with the side cover.**

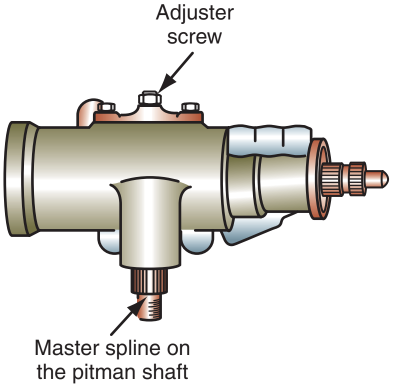
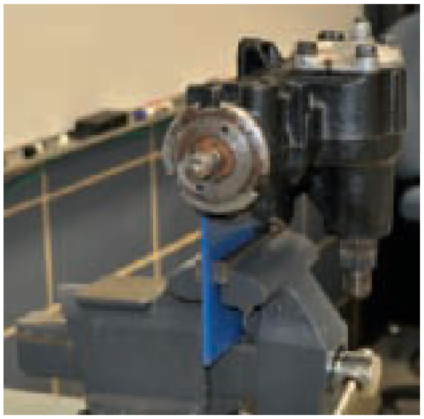


FIGURE 11-7 **Pitman shaft master spline aligned with the pitman backlash adjuster screw.**

Pitman Sector Shaft Lash Adjustment



P20-1. Clamp the steering gear securely in a vise.

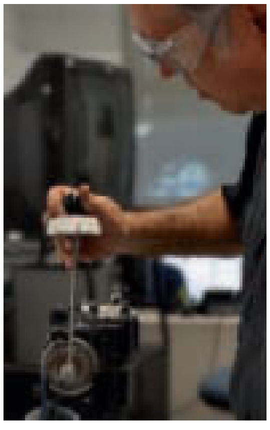
P20-2. Rotate the stub shaft from stop to stop and count the number of turns.

P20-3. Position the stub shaft at either stop and rotate the shaft back one-half the number of total turns.

P20-4. Be sure the master spline on the stub shaft is aligned with the pitman shaft backlash adjuster screw.

P20-5. Loosen the locknut and rotate the backlash adjuster screw fully counterclockwise, and then turn this screw clockwise one turn.

P20-6. Use an inch-pound torque wrench and the proper size socket to rotate the stub shaft through a 45° on each side of the stub shaft center position.



P20-7. Read the over-center torque reading on the torque wrench as the stub shaft is rotated through the center position.

P20-8. While rotating the stub shaft through the center position, turn the sector backlash adjuster screw until the torque wrench reading is 6–10 in-lb. (0.6–1.2 Nm) more than the torque reading in step 7.

P20-9. Hold the sector backlash adjuster screw in this position and tighten the locknut to the specified torque.

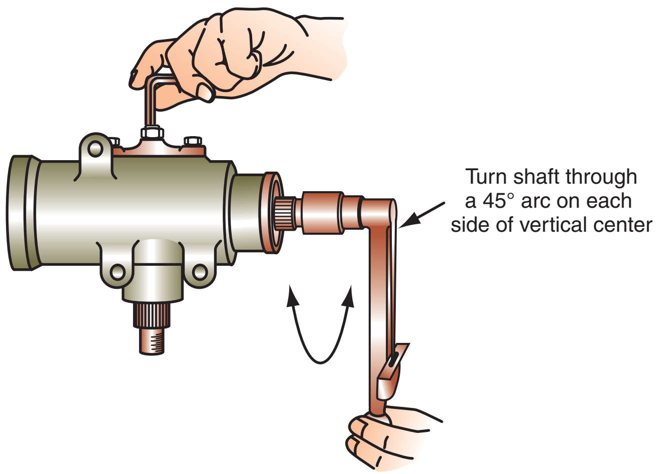


FIGURE 11-8 **Measuring wormshaft turning torque to adjust pitman backlash adjuster screw.**

Power Recirculating Ball Steering Gear Oil Leak Diagnosis

Five locations where oil leaks may occur in a power steering gear are the following:

1. Side cover O-ring seal (Figure 11-9)
2. Adjuster plug seal
3. Pressure line fitting
4. Pitman shaft oil seals
5. End cover seal

If an oil leak is present at any of these areas, complete or partial steering gear disassembly and seal or O-ring replacement is necessary.

Power Recirculating Ball Steering Gear Seal Replacement

Side Cover O-Ring Replacement

Prior to any disassembly procedure, clean the steering gear with solvent or in a parts washer. The steering gear service procedures vary depending on the make of gear. Always follow the vehicle manufacturer's recommended procedure in the service manual.

Following is a typical side cover O-ring replacement procedure:

1. Loosen the pitman backlash adjuster screw locknut and remove the side cover bolts. Rotate the pitman backlash adjuster screw clockwise to remove the cover from the screw (Figure 11-10).

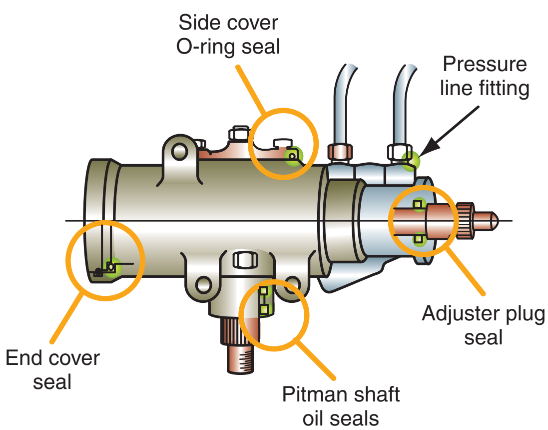


FIGURE 11-9 **Power recirculating ball steering gear oil leak locations.**

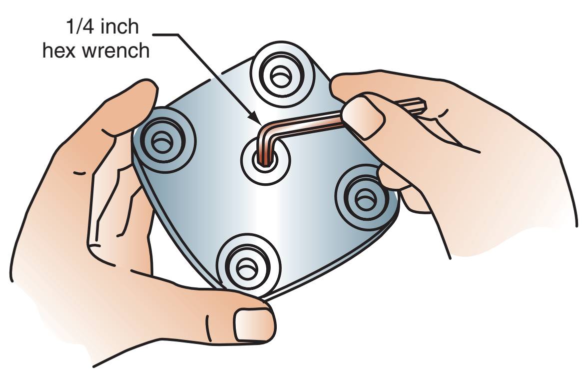


FIGURE 11-10 **Removing steering gear side cover.**

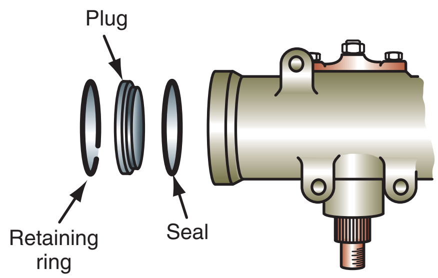


FIGURE 11-11 **Removing steering gear end plug, retaining ring, and seal.**

2. Discard the O-ring and inspect the side cover matching surfaces for metal burrs and scratches.
3. Lubricate a new O-ring with the vehicle manufacturer's recommended power steering fluid and install the O-ring.
4. Rotate the pitman backlash adjuster screw counterclockwise into the side cover until the side cover is properly positioned on the gear housing. Turn this adjuster screw fully counterclockwise and then one turn clockwise. Install and tighten the side cover bolts to the specified torque. Adjust the pitman sector shaft lash as explained earlier.

End Plug Seal Replacement

Follow these steps for end plug seal replacement:

1. Insert a punch into the access hole in the steering gear housing to unseat the retaining ring, and remove the ring (Figure 11-11).
2. Remove the end plug and seal.
3. Clean the end plug and seal contact area in the housing with a shop towel.
4. Lubricate a new seal with the vehicle manufacturer's recommended power steering fluid, and install the seal.
5. Install the end plug and retaining ring.

CAUTION: The bearing identification number must face the driving tool to prevent bearing damage during installation.

Worm Shaft Bearing Adjuster Plug Seal and Bearing Replacement

Follow these steps for worm shaft bearing adjuster plug seal and bearing service:

1. Remove the adjuster plug locknut, and use a special tool to remove the adjuster plug.
2. Use a screwdriver to pry at the raised area of the bearing retainer to remove this retainer from the adjuster plug (Figure 11-12).
3. Place the adjuster plug face down on a suitable support, and use the proper driver to remove the needle bearing, dust seal, and lip seal.
4. Place the adjuster plug face up on a suitable support, and use the proper driver to install the needle bearing dust seal and lip seal.

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CUSTOMER CARE: As an automotive technician, you should be familiar with the maintenance schedules recommended by various vehicle manufacturers. Of course, it is impossible to memorize all the maintenance schedules on different makes of vehicles, but maintenance schedule books are available. This maintenance schedule information is available in the owner's manual, but the vehicle owner may not take time to read this manual. If you advise the customer that his or her vehicle requires some service, such as a cooling system flush, according to the vehicle manufacturer's maintenance schedule, the customer will often have the service performed. The customer will usually appreciate your interest in his or her vehicle, and the shop will benefit from the increased service work.

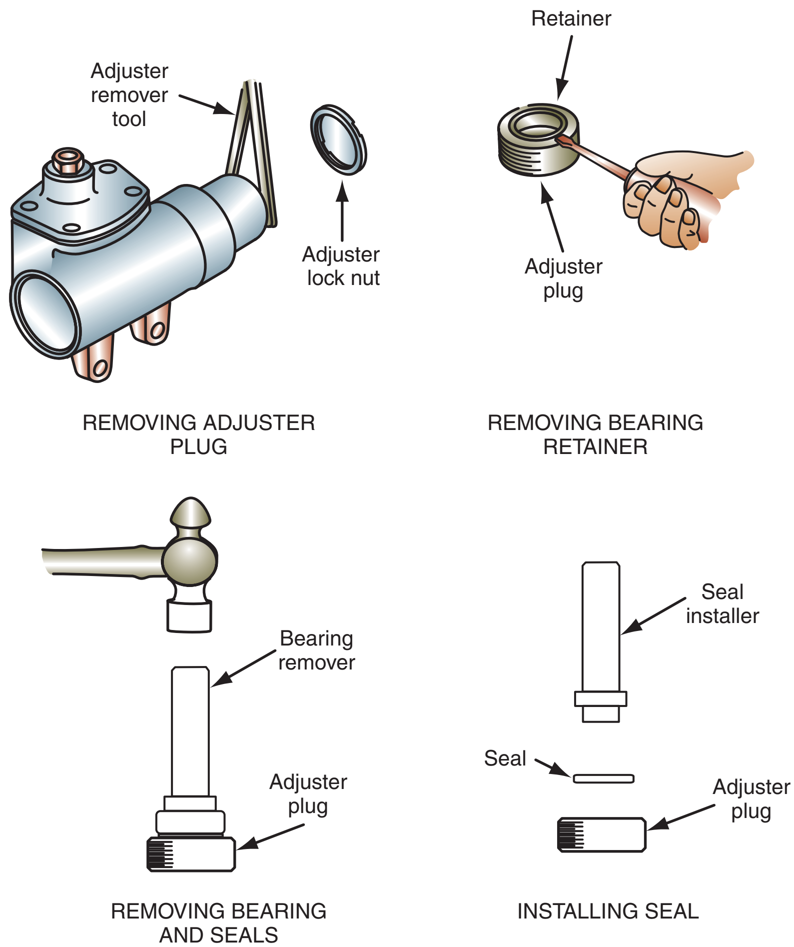

FIGURE 11-12 **Removing and replacing worm shaft adjuster plug, bearing, and seal.**

5. Install the bearing retainer in the adjuster plug, and lubricate the bearing and seal with the vehicle manufacturer's recommended power steering fluid.
6. Install the adjuster plug and locknut, and adjust the worm shaft bearing preload as discussed previously.

TABLE 11-1 **STEERING GEAR DIAGNOSIS**

Problem	**Symptoms**	**Possible Causes**
Excessive steering wheel free play	Steering wander when driving straight ahead	Loose worm shaft preload adjustment Losse sector lash adjustment Loose steering gear mounting bolts Worn steering linkage components Worn flexible coupling or universal joint in steering shaft.
Excessive steering effort	Excessive steering wheel turning effort when turning a corner or parking	Lack of steering gear lubricant Tight worm shaft bearing preload adjustment Tight sector lash ajdustment
Underhood noise	Rattling noise when driving over road irregularities Squawking noise while turning a corner	Worn flexible coupling or universal joint in steering shaft Loose steering gear mounting bolts Cut or worn dampener O-ring on spool valve
Erratic steering effort	Erratic steering effort when turning a corner	Low power steering fluid level Air in power steering system Worn, damaged worm shaft, ball nut, or sector teeth

Terms to Know

Bearing preload
Sector shaft lash
Road feel
Steering wheel free play
Vehicle wander

CASE STUDY

The owner of a 2005 Chevrolet Silverado truck complained about increased and somewhat erratic steering effort. The service writer asked the customer about the conditions when this problem occurred, and the customer said that the condition was always present. During a road test, the technician discovered that the customer's description of the problem was accurate.

The technician checked the power steering fluid level and made a careful check of the belt tension and condition without finding any problems. Next, the technician checked the power steering pump pressure and found it to be normal. A check of the power steering hoses did not reveal any hose restrictions.

The technician removed and disassembled the steering gear and found a severely scored cylinder bore in the gear housing. The ball nut piston ring was also worn and scored. A replacement steering gear was installed, and the system filled with the manufacturer's recommended power steering fluid. A road test indicated the new gear worked satisfactorily.

ASE-Style Review Questions

1. While discussing power recirculating ball steering gear diagnosis:
   Technician A says excessive steering wheel free play may be caused by a worm shaft bearing preload adjustment that is tighter than normal.
   Technician B says excessive steering wheel free play may be caused by loose steering gear mounting bolts.
   Who is correct?
   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

2. While discussing power recirculating ball steering gear service:
   Technician A says steering wander may be caused by a loose sector lash adjustment.
   Technician B says a loose sector lash adjustment may cause reduced feel of the road.
   Who is correct?
   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

3. While discussing power recirculating steering gear diagnosis:
   Technician A says the sector lash adjustment is performed with the worm shaft halfway between the centered position and the full-right position.
   Technician B says the worm shaft bearing preload adjustment is performed before the sector lash adjustment.
   Who is correct?
   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

4. A power recirculating ball steering gear has a rattling noise while driving the vehicle. The most likely cause of this problem is:
   A. Low power steering fluid level.
   B. Worn flexible coupling in the steering shaft.
   C. Loose worm bearing preload adjustment.
   D. Leaking pitman shaft seal.

5. A power recirculating ball steering gear has a fluid leakage problem, and fluid appears on the top of the gear.
   Technician A says the side cover O-ring seal may be leaking.
   Technician B says the high pressure line fitting on the gear may be leaking.
   Who is correct?
   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

6. A power recirculating ball steering gear has excessive kickback on the steering wheel. The most likely cause of this problem is:
   A. A loose sector lash adjustment.
   B. A loose worm shaft bearing preload adjustment.
   C. A defective poppet valve in the steering gear.
   D. A worn pitman shaft bearing.

7. All of these statements about power recirculating ball steering gear defects are true EXCEPT:
   A. A worn steering shaft U-joint may cause a growling noise when turning the front wheels.
   B. Excessive steering effort may be caused by a defective power steering pump.
   C. Excessive steering effort may be caused by a scored steering gear cylinder.
   D. Steering wheel jerking when turning may be caused by a slipping power steering belt.
8. When adjusting on a power recirculating ball steering gear:
   A. The worm shaft bearing adjuster plug should be bottomed and then backed off until the specified worm shaft turning torque is obtained.
   B. The sector lash adjustment screw should be tightened one turn before the worm shaft bearing preload is adjusted.
   C. The pitman shaft backlash adjuster screw is turned fully counterclockwise and then one turn clockwise prior to the backlash adjustment.
   D. The pitman shaft is positioned one-half turn from the fully right or left position prior to the pitman shaft backlash adjustment.
9. A power recirculating ball steering gear experiences excessive steering effort while parking. The most likely cause of this problem is:
   A. A restricted high-pressure steering hose.
   B. A misaligned power steering belt.
   C. A leaking pitman shaft seal.
   D. Excessive torque on the worm shaft adjuster plug locknut.
10. A power recirculating ball steering gear experiences hard steering for a short time after the vehicle sits overnight. The most likely cause of this problem is:
   A. Excessively tight worm bearing preload adjustment.
   B. A scored cylinder and worn piston ring in the steering gear.
   C. A restricted power steering return hose.
   D. A binding U-joint in the steering shaft.

ASE Challenge Questions

1. A car with a power recirculating ball steering gear has excessive steering kickback, and a preliminary inspection shows no abnormal wear in the linkage. Which of the following could be the cause of the problem?
   A. Worn gear piston or bore.
   B. Slipping pump belt.
   C. Worn pump poppet valve.
   D. Sticking valve spool.
2. The complaint is loss of power assist, but there is no mention of any associated noise. All of the following could cause this problem EXCEPT:
   A. Low fluid.
   B. Improperly inflated tires.
   C. Broken pump belt.
   D. Steering column misalignment.
3. While discussing steering problems:

   Technician A says a "jerky" steering wheel and a "clunking" noise could indicate worn steering column U joints.

   Technician B says lack of assist and a "growling" noise in a fluid-filled steering pump could indicate a hose or pump internal restriction.

   Who is correct?

   A. A only   C. Both A and B
   B. B only   D. Neither A nor B

4. A vehicle with a power recirculating ball steering system requires much higher than normal steering effort, especially in the parking lot.

   Technician A says the cause of the problem is a worn pitman shaft seal.

   Technician B says the cause of the problem is a worn worm shaft thrust bearing.

   Who is correct?

   A. A only C. Both A and B

   B. B only D. Neither A nor B

5. The complaint is excessive steering wheel free play. All of the following could cause this problem EXCEPT:

   A. Loose worm shaft bearing preload.

   B. Worn steering gears.

   C. Steering gear column misalignment.

   D. Worn flex coupling or U joint.

Name ______________________________ Date ____________________

Power Recirculating Ball Steering Gear Oil Leak Diagnosis

Upon completion of this job sheet, you should be able to diagnose oil leaks in a power recirculating ball steering gear.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-4: Diagnose power steering gear (non-rack and pinion) binding, uneven turning effort, looseness, hard steering, and noise concerns, determine necessary action.

Tools and Materials

Modern vehicle with a power recirculating ball steering gear.

Describe the Vehicle Being Worked On:

Year ______________ Make ______________ Model ______________________

VIN ________________________ Engine type and size ______________________

Procedure

Task Completed

1. Place fender, seat, and floor mat covers on the vehicle. ☐
2. Clean the outside of the steering gear.
3. Be sure the power steering pump reservoir is filled to the proper level with the specified fluid.
4. Start the engine and observe the power steering gear while an assistant turns the steering wheel fully in each direction several times. Turn off the ignition switch.
5. If the power steering gear is leaking fluid on the lower side, raise the front of the vehicle with a floor jack and support the front suspension on safety stands positioned at the specified vehicle lift points. Repeats steps 2–4.
6. List the fluid leak locations on the power steering gear.
   ____
   ____
7. State the necessary repairs to correct the power steering gear leaks.
   ____
   ____

Instructor's Response ______________________________________

____

____

____

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Name ______________________________ Date ____________________

Adjust Power Recirculating Ball Steering Gear Worm Shaft Thrust Bearing Preload, Steering Gear Removed

Upon completion of this job sheet, you should be able to adjust worm shaft thrust bearing preload on power recirculating ball steering gears.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-7: Adjust non-rack and pinion worm bearing preload and sector lash.

Tools and Materials

Torque wrench, in-lb.

Describe the Vehicle Being Worked On:

Year _____________ Make _____________ Model ____________________

VIN ______________________ Engine type and size ____________________

Make of steering gear ____

Procedure

Task Completed

1. Remove the worm shaft thrust bearing adjuster plug locknut with a hammer and brass punch. ☐
2. Turn this adjuster plug inward, or clockwise, until it bottoms and tighten the plug to 20 ft-lb. (27 Nm).

   Actual worm shaft adjuster plug locknut torque ________________________
3. Place an index mark on the steering gear housing next to one of the holes in the adjuster plug.
   Is an index mark placed on steering gear housing beside one of the adjuster plug holes?
   ☐ Yes ☐ No

   Instructor check ____
4. Measure 0.50 in. (13 mm) counterclockwise from the index mark, and place a second index mark at this position.
   Is a second index mark placed 0.50 in. (13 mm) counterclockwise from the first index mark?
   ☐ Yes ☐ No

   Instructor check ____

Task Completed ________

5. Rotate the adjuster plug counterclockwise until the hole in the adjuster plug is aligned with the second index mark placed on the housing.

Is the hole in adjuster plug properly aligned with second index mark?

☐ Yes ☐ No

Instructor check ________________

6. Install and tighten the adjuster plug locknut to the specified torque.

Specified adjuster plug locknut torque ________________

Actual adjuster plug locknut torque ________________

Instructor's Response ________________

____

____

____

Name ______________________________ Date ____________________

Adjust Power Recirculating Ball Steering Gear Sector Lash, Steering Gear Removed

Upon completion of this job sheet, you should be able to adjust sector lash on power recirculating ball steering gears.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-7: Adjust non-rack and pinion worm bearing preload and sector lash.

Tools and Materials

Torque wrench, in-lb.

Describe the Vehicle Being Worked On:

Year _____________ Make _____________ Model ____________________

VIN ______________________ Engine type and size ____________________

Make of steering gear ____

Procedure

Task Completed

1. Rotate the worm shaft from stop to stop and count the number of turns.

   Total number of worm shaft turns from stop to stop ______________________

2. Starting at either stop, turn the worm shaft back two-thirds of the total number of turns.

   Number of worm shaft turns from fully right or fully left to position the worm shaft properly prior to sector lash adjustment ______________________

   Explain the reason for placing the worm shaft in this position prior to the sector lash adjustment.

   ____

   ____

   ____

3. In this position, the flat on the worm shaft should be facing upward, and the master spline on the pitman shaft should be aligned with the pitman shaft backlash adjuster screw.

   Is the worm shaft flat properly positioned? ☐ Yes ☐ No

   Is the master spline on the pitman shaft properly positioned? ☐ Yes ☐ No

   If the answer is no to either of the above questions, state the necessary corrective action.

   ____

   ____

Task Completed

4. Turn the pitman shaft backlash adjuster screw fully counterclockwise, and then turn it clockwise one turn.

   Is the pitman shaft backlash adjuster screw properly positioned? ☐ Yes ☐ No

   Instructor check ______________________________

5. Use an inch-pound torque wrench to turn the worm shaft through a 45° arc on each side of the position in step 2. Read the over-center torque as the worm shaft turns through the center position.

   Stub shaft turning torque______________________________

6. Continue to adjust the pitman shaft adjuster screw until the torque is 6 to 10 in-lb. (0.6 to 1.2 Nm) more than the torque in step 5.

   Final worm shaft turning torque after adjustment ______________________________

7. Hold the pitman shaft adjuster screw in this position and tighten the locknut to the specified torque.

   Specified pitman shaft adjuster screw locknut torque ______________________________

   Actual pitman shaft adjuster screw locknut torque ______________________________

Instructor's Response ______________________________

____

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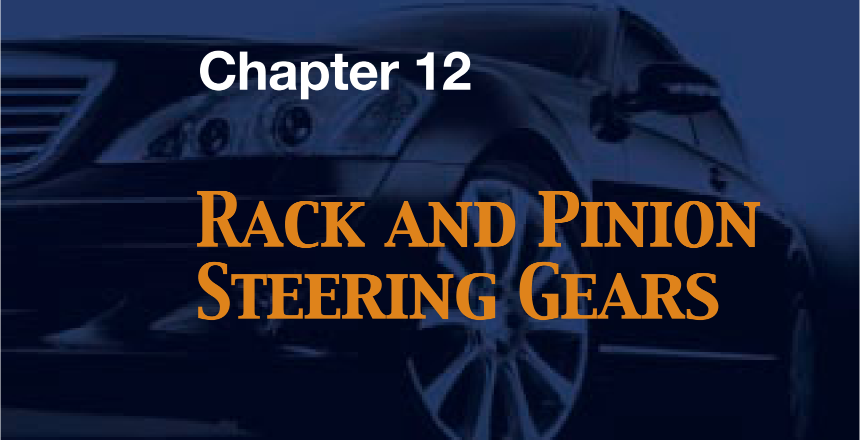

Chapter 12

Rack and Pinion Steering Gears

Upon completion and review of this chapter, you should be able to understand and describe:

- The advantages of a rack and pinion steering system compared to a recirculating ball steering gear and parallelogram steering linkage.
- How the tie-rods are connected to the rack.
- The purpose of the rack bearing and adjuster plug.
- Two possible mounting positions for the rack and pinion steering gear.
- The fluid movement in a rack and pinion steering gear during a right turn.
- The fluid movement in a rack and pinion steering gear during a left turn.
- The operation of the spool valve and rotary valve.
- The operation of the power rack and pinion steering gear when hydraulic pressure is not available.
- The purpose of the breather tube.
- The main differences between a Saginaw and a TRW power rack and pinion steering gear.
- The advantages of an electronic variable orifice (EVO) steering system.
- The input sensors in an EVO steering system.
- The driving conditions when an EVO steering system provides increased power steering assistance.
- The operation of a rack-drive electronic power steering system during right and left turns.
- The operation of the steering shaft torque sensor in a column-drive electronic power steering system.
- The operation and advantages of active front steering (AFS).

Introduction

During the late 1970s and 1980s, the domestic automotive industry converted much of its production from larger rear-wheel-drive (RWD) cars to smaller, lightweight, and more fuel efficient front-wheel-drive (FWD) cars. These FWD cars required smaller, lighter components wherever possible. Manual and power rack and pinion steering gears are lighter and more compact than the recirculating ball steering gears and parallelogram steering linkages used on most RWD cars. Therefore, rack and pinion steering gears are ideally suited to these compact FWD cars.

Steering systems have not escaped the electronics revolution. Many cars are presently equipped with electronic variable orifice (EVO) steering, which provides greater power assistance during low-speed cornering and parking for increased driver convenience. Some cars are now equipped with electronic power steering. In these systems, an electric motor in the steering gear provides steering assist.

Manual Rack and Pinion Steering Gear Main Components

Rack

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The **rack** is a toothed bar that slides back and forth in a metal housing. The steering gear housing is mounted in a fixed position on the front crossmember or on the firewall. The rack takes the place of the idler and pitman arms in a parallelogram steering system and maintains the proper height of the tie-rods so they are parallel to the lower control arms. The rack may be compared to the center link in a parallelogram steering linkage. Bushings support the rack in the steering gear housing. Sideways movement of the rack pulls or pushes the tie-rods and steers the front wheels (Figure 12-1).

Pinion

Spur gear teeth are cut so they are parallel to the gear rotational axis.

The **pinion** is a toothed shaft mounted in the steering gear housing so the pinion teeth are meshed with the rack teeth. The pinion may contain **spur gear teeth** or **helical gear teeth**. The upper end of the pinion shaft is connected to the steering shaft from the steering column. Therefore, steering wheel rotation moves the rack sideways to steer the front wheels. The pinion is supported on a ball bearing in the steering gear housing.

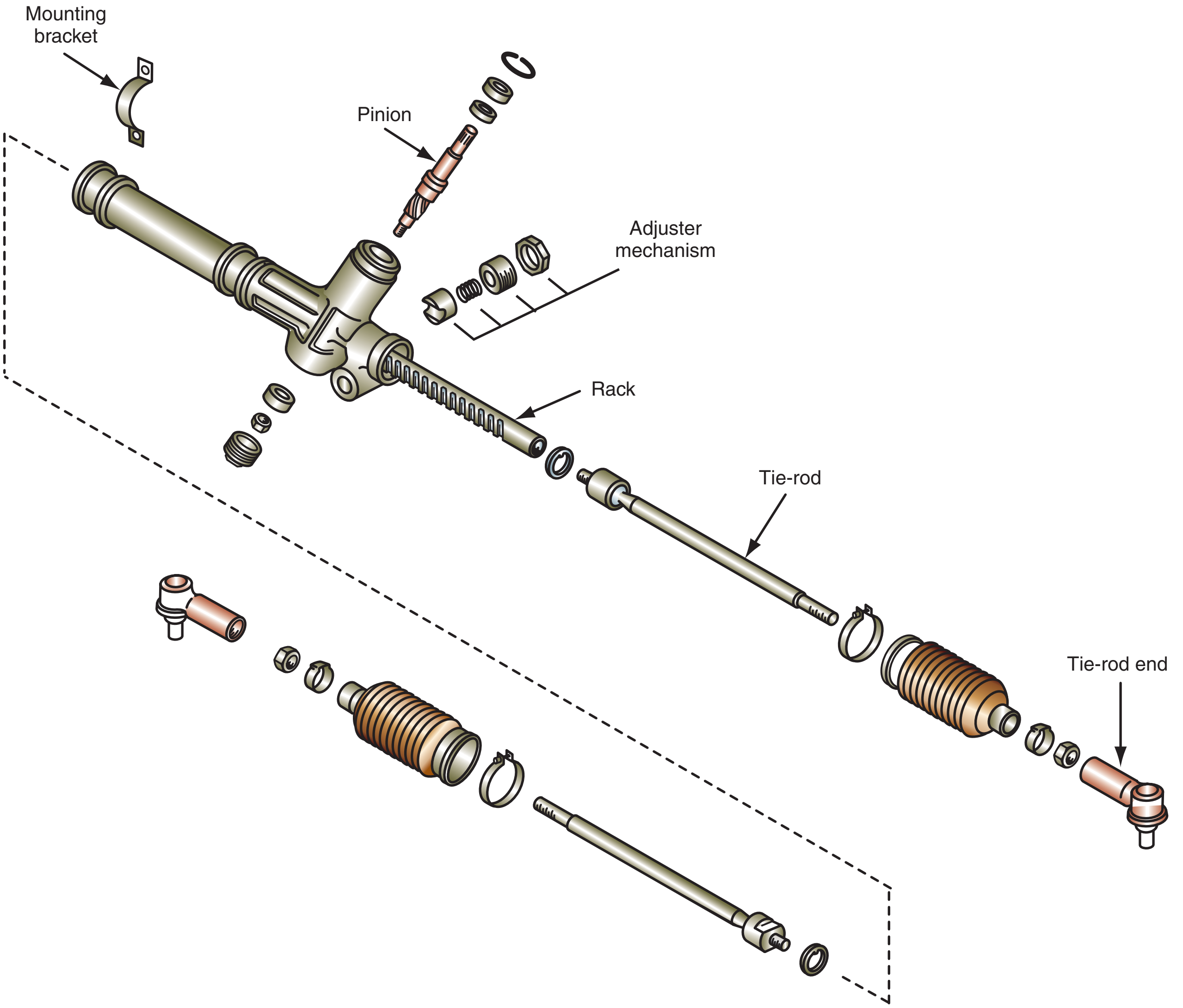

FIGURE 12-1 **Manual rack and pinion steering gear components.**

Tie-Rods and Tie-Rod Ends

The tie-rods are similar to those used on parallelogram steering linkages. A spring-loaded ball socket on the inner end of the tie-rod is threaded onto the rack. When these ball sockets are torqued to the vehicle manufacturer's specification, a preload is placed on the ball socket. A bellows boot is clamped to the housing and tie-rod on each side of the steering gear, and these boots keep contaminants out of the ball socket and rack.

A tie-rod end is threaded onto the outer end of each tie-rod. These tie-rod ends are similar to those used on parallelogram steering linkages. A jam nut locks the outer tie-rod end to the tie-rod.

Helical gear teeth are curved to increase the amount of tooth contact between a pair of meshed gears. Helical gears tend to operate more quietly than spur gear teeth and provide increased strength compared with spur gear teeth.

Rack Adjustment

A rack bearing is positioned against the smooth side of the rack. A spring is located between the rack bearing and the rack adjuster plug that is threaded into the housing. This adjuster plug is retained with a locknut. The rack bearing adjustment sets the preload between the rack and pinion teeth, which affects **steering kickback**, harshness, and noise.

Steering kickback is the movement of the steering wheel caused by a front wheel striking a road irregularity.

Steering Gear Ratio

When the steering wheel is rotated from **lock-to-lock** or **stop-to-stop**, the front wheels turn about 30° each in each direction from the straight-ahead position. Therefore, the total front wheel movement from left to right is approximately 60°. With a steering ratio of 1:1, 1° of steering wheel rotation would turn the front wheels 1°, and 30° of steering wheel rotation in either direction would result in lock-to-lock front wheel movement. This steering ratio is much too extreme because the slightest steering wheel movement would cause the vehicle to swerve. The steering gear must have a ratio that allows more steering wheel rotation in relation to front wheel movement.

Rotation of the steering wheel from extreme left to extreme right is called **lock-to-lock** or **stop-to-stop**.

A **steering ratio** of 15:1 is acceptable, and this ratio provides 1° of front wheel movement for every 15° of steering wheel rotation. To calculate the steering ratio, divide the lock-to-lock steering wheel rotation in degrees by the total front wheel movement in degrees. For example, if the lock-to-lock steering wheel rotation is 3.5 turns, or 1,260°, and the total front wheel movement is 60°, the steering ratio is 1,260 ÷ 60 = 21:1. As a general rule, large, heavy cars have higher numerical steering ratios than small, lightweight cars.

Steering ratio is the relationship between steering wheel rotation in degrees and front wheel movement to the right or left in degrees.

Manual Rack and Pinion Steering Gear Mounting

Large rubber insulating grommets are positioned between the steering gear and the mounting brackets. These bushings help prevent the transfer of road noise and vibration from the steering gear to the chassis and passenger compartment. The rack and pinion steering gear may be attached to the front crossmember or to the cowl. Proper steering gear mounting is important to maintain the parallel relationship between the tie-rods and the lower control arms. The firewall is reinforced at the steering gear mounting locations to maintain the proper steering gear position.

Advantages and Disadvantages of Rack and Pinion Steering

As mentioned earlier, the rack and pinion steering gear is lighter and more compact than a recirculating ball steering gear and parallelogram steering linkage. Therefore, the rack and pinion steering gear is most suitable for FWD unibody vehicles.

Since there are fewer friction points in the rack and pinion steering than in the recirculating ball steering gear with a parallelogram steering linkage, the driver has a greater feeling of the road with rack and pinion steering gear. However, fewer friction points reduce the steering system's ability to isolate road noise and vibration. Therefore, drivers of a vehicle with

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The **rack piston** is attached to the rack, and this piston moves horizontally in the steering gear chamber.

Rack seals are mounted at each end of the rack chamber and on the rack piston. The seals at each end of the rack chamber prevent leaks between the rack and the chamber.

a rack and pinion steering system may have more complaints of road noise and vibration transfer to the steering wheel and passenger compartment.

Power Rack and Pinion Steering Gears

Design and Operation

A power-assisted rack and pinion steering gear uses the same basic operating principles as a manual rack and pinion steering gear, but in the power-assisted steering gear, hydraulic fluid pressure from the power steering pump is used to reduce steering effort. A **rack piston** is integral with the rack, and this piston is located in a sealed chamber in the steering gear housing. Hydraulic fluid lines are connected to each end of this chamber, and **rack seals** are positioned in the housing at ends of the chamber. A seal is also located on the rack piston (Figure 12-2).

When a driver is completing a left turn, fluid is pumped into the left side of the fluid chamber and exhausted from the right chamber area. This hydraulic pressure on the left side of the rack piston helps the pinion move the rack to the right (Figure 12-3, view A).

When a right turn is made, fluid is pumped into the right side of the fluid chamber, and fluid flows out of the left end of the chamber. Thus, hydraulic pressure is exerted on the right side of the rack piston, which assists the pinion gear in moving the rack to the left (Figure 12-3,

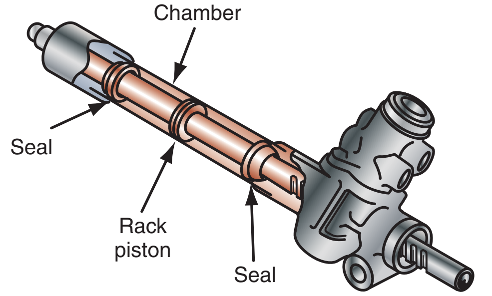

FIGURE 12-2 **Hydraulic chamber in a power rack and pinion steering gear.**

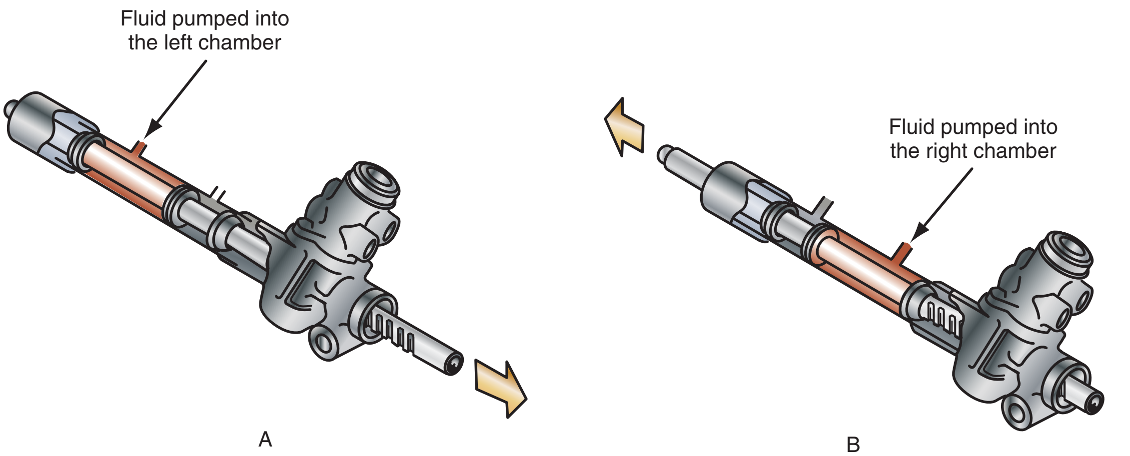

FIGURE 12-3 **Rack movement during left and right turns.**

view B). Since the steering gear is mounted behind the front wheels, rack movement to the left is necessary for a right turn, whereas rack movement to the right causes a left turn.

Rotary Valve and Spool Valve Operation

Fluid direction in the steering gear is controlled by a rotary valve attached to the pinion assembly (Figure 12-4). A stub shaft on the pinion assembly is connected to the steering shaft and wheel. The pinion is connected to the stub shaft through a **torsion bar** that twists when the steering wheel is rotated and springs back to the center position when the wheel is released. A rotary valve body contains an inner **spool valve** that is mounted over the torsion bar on the pinion assembly.

Torsion bar twisting during steering wheel rotation moves the spool valve in relation to the rotary valve.

When the front wheels are in the straight-ahead position, fluid flows from the pump through the high-pressure hose to the center **rotary valve** body passage. Fluid is then routed through the valve body to the low-pressure return hose and the pump reservoir (Figure 12-5).

The **rotary valve** is mounted over the spool valve on the steering gear pinion.

Many power steering systems contain a fluid cooler connected in the high-pressure hose between the pump and the steering gear. The fluid cooler is like a small radiator. Air flows through the fins on the cooler and cools the fluid flowing through the internal cooler passages. Some power steering systems have a remote fluid reservoir connected in the low pressure hose between the steering gear and the pump (Figure 12-5). Many power steering systems have a fluid filter, and this filter is often mounted in the remote reservoir.

Teflon rings or O-rings seal the rotary valve ring lands to the steering gear housing. A lot of force is required to turn the pinion and move the rack because of the vehicle weight on the front wheels. When the driver turns the wheel, the stub shaft is forced to turn. However, the pinion resists turning because it is in mesh with the rack, which is connected to the front wheels. This resistance of the pinion to rotation results in torsion bar twisting. During this twisting action, a pin on the torsion bar moves the spool valve with a circular motion inside the rotary valve. If the driver makes a left turn, the spool valve movement aligns the inlet center rotary valve passage with the outlet passage to the left side of the rack piston. Therefore, hydraulic fluid pressure applied to the left side of the rack piston assists the driver in moving the rack to the right.

When the driver turns the steering wheel, the amount of feeling that he or she senses regarding front wheel turning is called **feel of the road**.

When a right turn is made, twisting of the torsion bar moves the spool valve and aligns the center rotary valve passage with the outlet passage to the right side of the rack piston (Figure 12-6). Under this condition, hydraulic fluid pressure applied to the rack piston helps the driver move the rack to the left. The torsion bar provides a **feel of the road** to the driver.

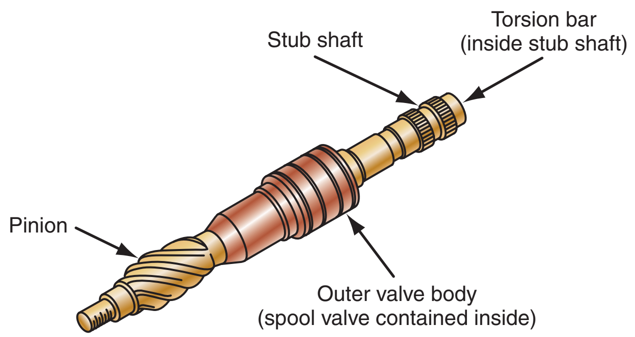

FIGURE 12-4 **Pinion assembly for a power rack and pinion steering gear.**

Item	Part Number	Description
1	3A697	Fluid reservoir (early build vehicles)
2	3A697	Fluid reservoir (late build vehicles)
3	3691	Supply hose (reservoir-to-pump) (early build vehicles)
4	3A713	Return hose (cooler-to-reservoir) (early build vehicles)
5	3691	Supply hose (reservoir-to-pump) (late build vehicles)
6	3A713	Return hose (cooler-to-reservoir) (late build vehicles)
7	3489	Fluid reservoir bracket (early build vehicles)
8	3A733	Pulley
9	3A764	Power steering pump
10	3504	Steering gear
11	3A131	Tie-rod end
12	3280	Inner tie-rod
13	3332	Inner tie-rod boot
14	3A713	Return line (gear-to-cooler)
15	3D746	Fluid cooler
16	3A719	Pressure line (pump-to-gear)
17	9F274	Return hose retainer clip
18	3F886-AA/ 3F886-BA	O-ring (1 each required)

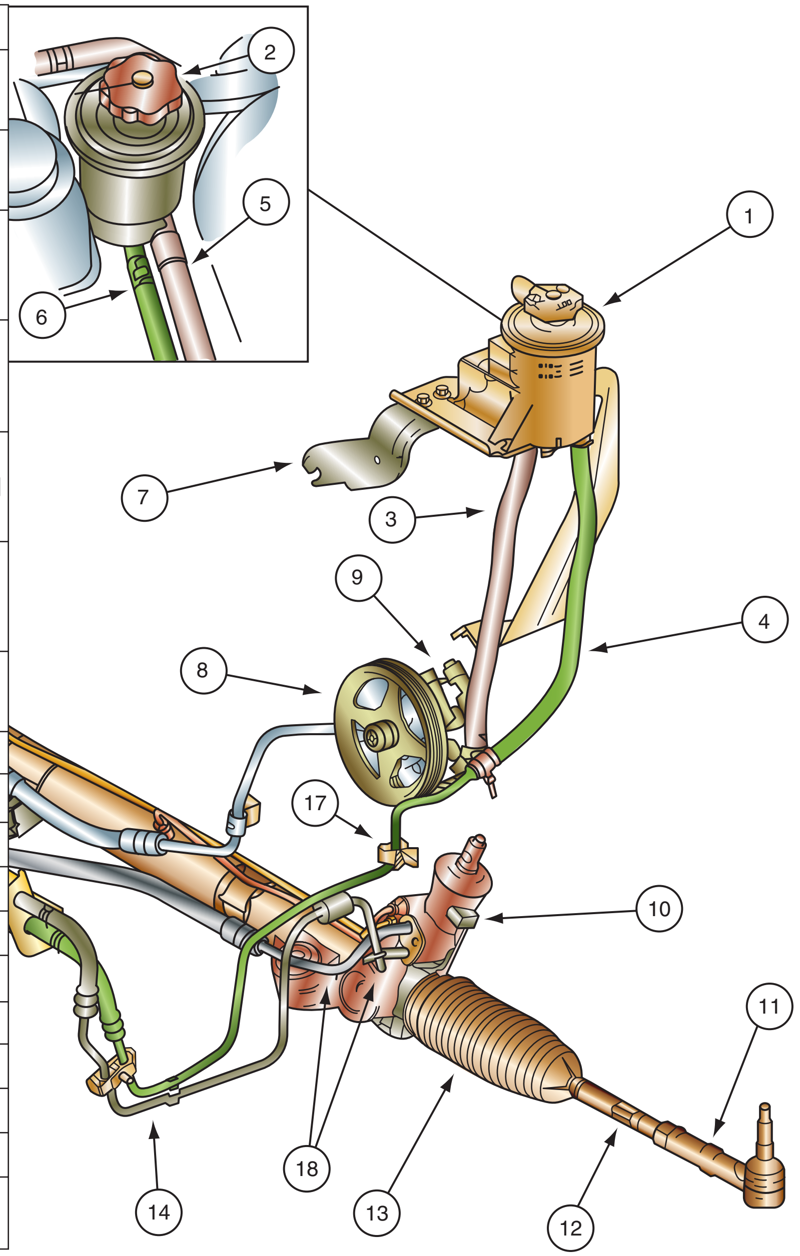

FIGURE 12-5 **Power rack and pinion steering gear with connecting hoses and lines.**

In power rack and pinion steering gears, a condition that causes excessive steering wheel turning effort when the vehicle is first started may be called "morning sickness."

When the steering wheel is released after a turn, the torsion bar centers the spool valve and power assistance stops. If hydraulic fluid pressure is not available from the pump, the power steering system operates like a manual system, but steering effort is higher. When the torsion bar is twisted to a designed limit, tangs on the stub shaft engage with drive tabs on the pinion. This action mechanically transfers motion from the steering wheel to the rack and front wheels. Since hydraulic pressure is not available on the rack piston, greater steering effort is required. If a front wheel raises going over a bump or drops into a hole, the tie-rod pivots along with the wheel. However, the rack and tie-rod still maintain the left-to-right wheel direction.

The rack boots are clamped to the housing and the rack. Since the boots are sealed and air cannot be moved through the housing, a **breather tube** is necessary to move air from one boot to the other when the steering wheel is turned (Figure 12-7). This air movement through the vent tube prevents pressure changes in the bellows boots during a turn.

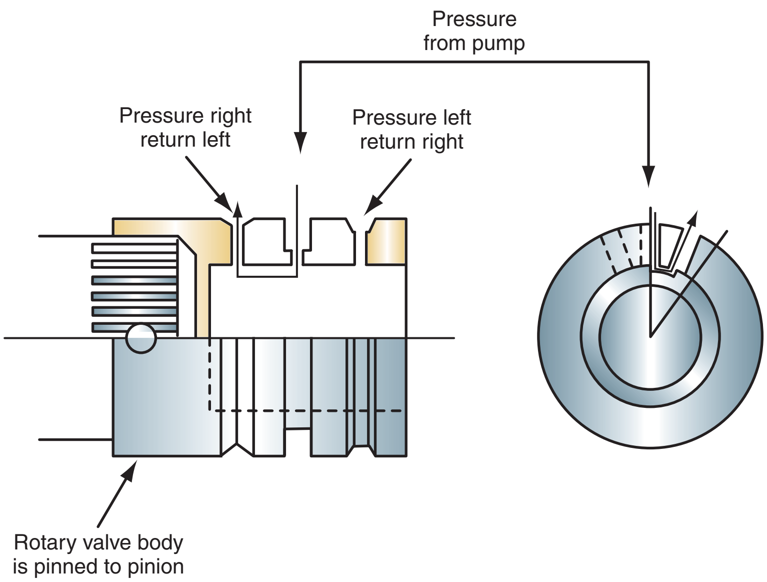

FIGURE 12-6 **Spool valve movement inside the rotary valve.**

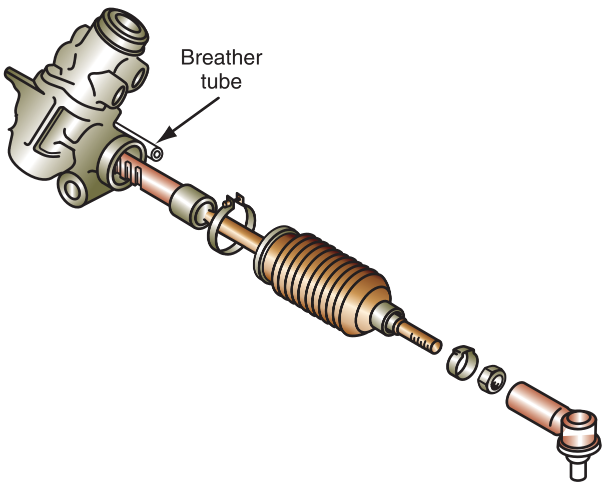

FIGURE 12-7 **Breather tube and boot.**

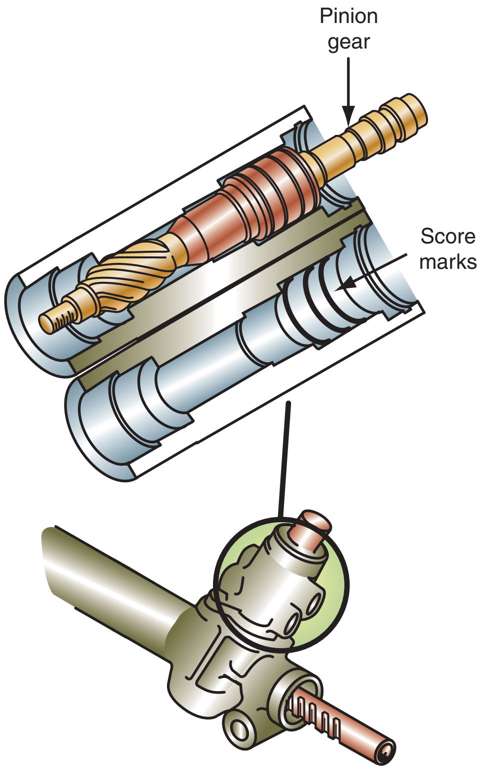

FIGURE 12-8 **Score marks in a rack and pinion steering gear housing.**

AUTHOR'S NOTE: It has been my experience that one of the most common problems with power rack and pinion steering gears is a condition that causes excessive steering wheel turning effort when the vehicle is first started in the morning. After the steering wheel is turned several times the condition disappears. This problem is caused by grooves worn in the aluminum pinion housing by the seals on the control valve (Figure 12-8). When this condition is present, steering gear replacement is usually required. As an automotive technician, you will be required to diagnose and correct this problem.

Types of Power Rack and Pinion Steering Gears

Power Rack and Pinion Steering Gear

Many vehicles have a rack and pinion steering gear manufactured by Saginaw (Figure 12-9). Some vehicles are equipped with a TRW rack and pinion steering gear. This type of steering gear is similar to the Saginaw gear except for the following differences:

1. Method of tie-rod attachment
2. Bulkhead oil seal and retainer
3. Pinion upper and lower bearing hardware

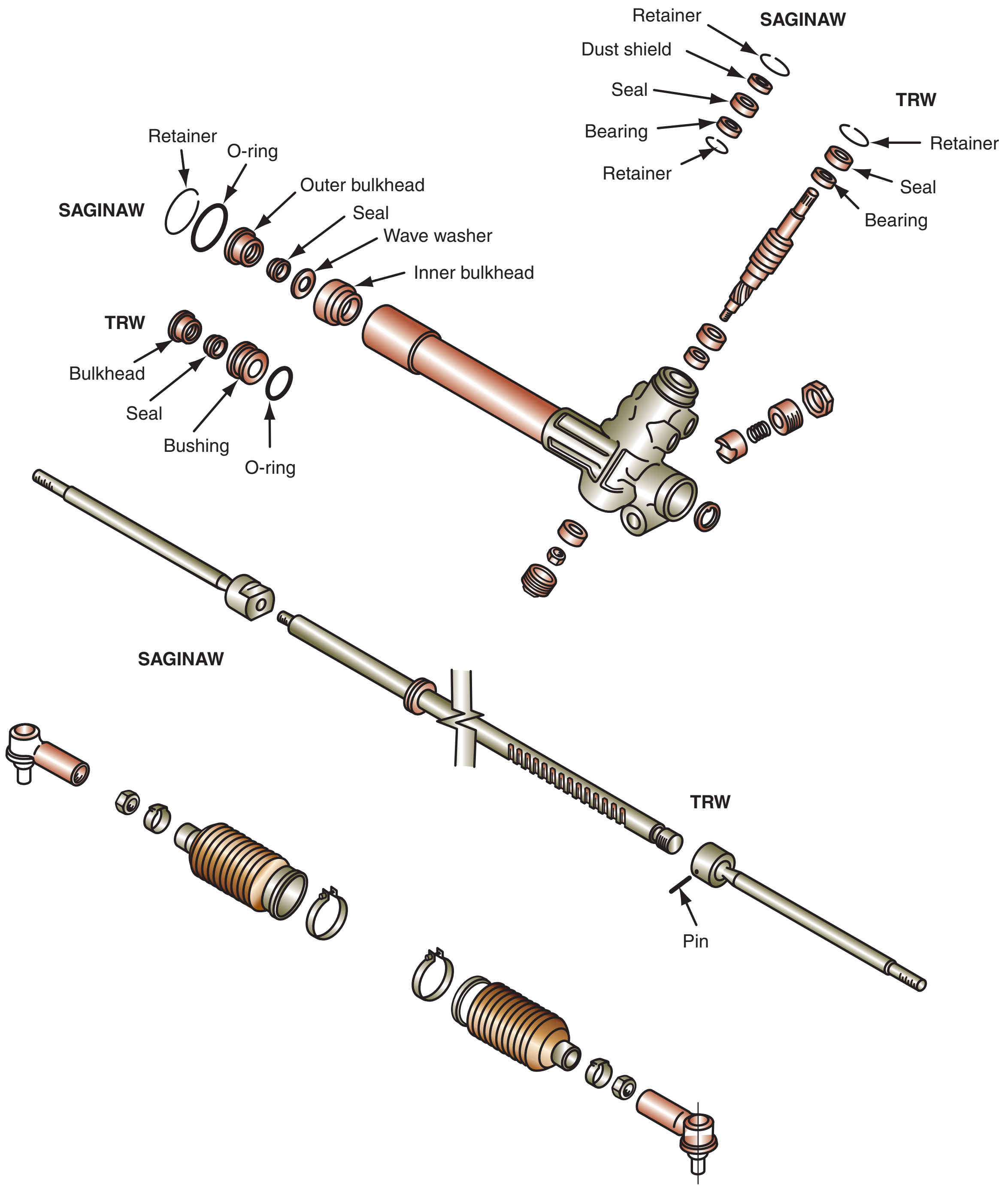

FIGURE 12-9 **Saginaw and TRW power rack and pinion steering gear.**

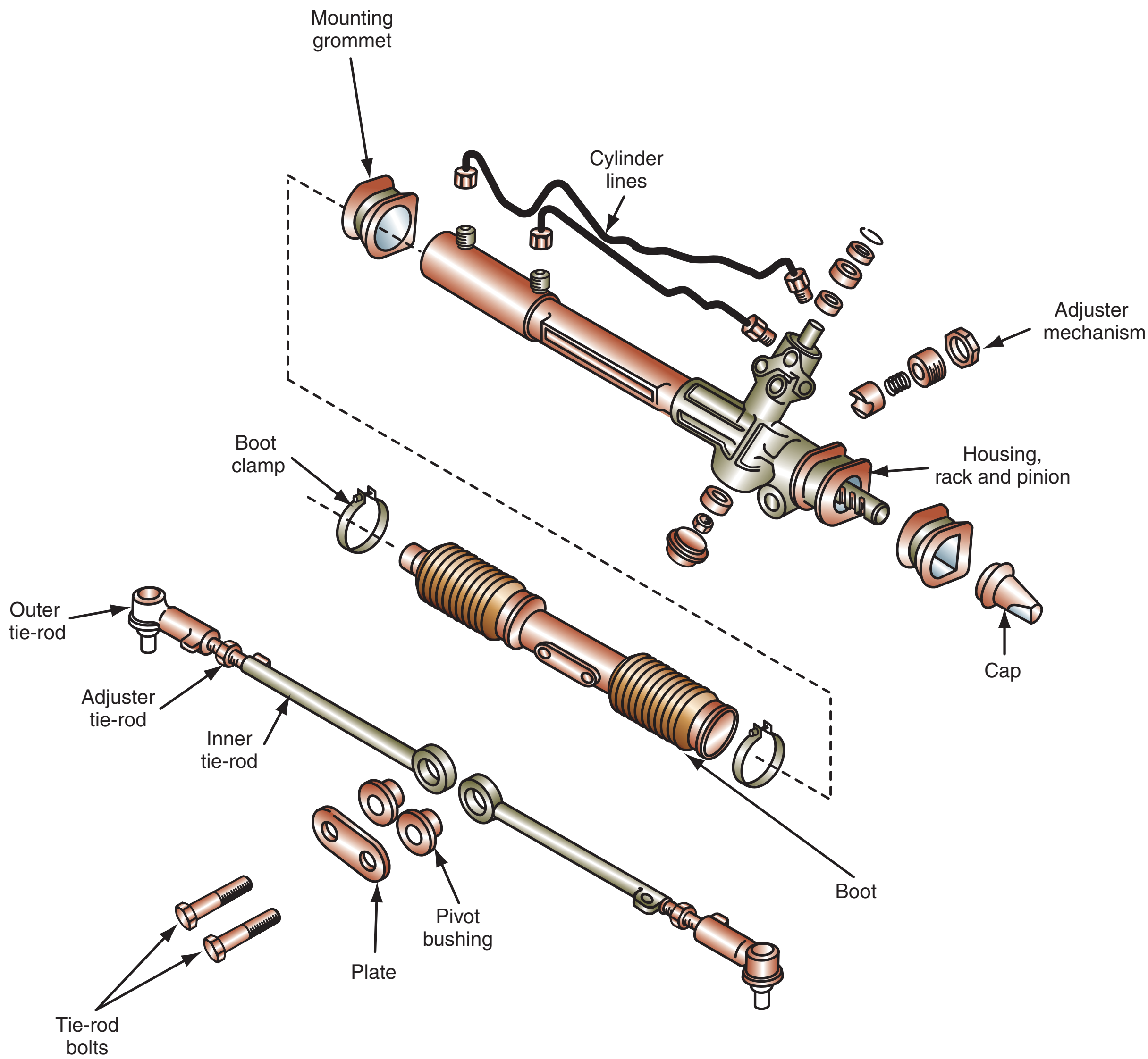

FIGURE 12-10 **Power rack and pinion steering gear with center take-off tie-rods.**

On both the Saginaw and TRW power rack and pinion steering gears, the tie-rods are connected to the ends of the rack. This type of steering gear may be referred to as **end take-off (ETO)**. On other power rack and pinion steering gears, the rack piston and cylinder are positioned on the right end of the rack and the tie-rods are attached to a movable sleeve in the center of the gear (Figure 12-10). This type of steering gear may be called **center take-off (CTO)**.

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The Toyota power rack and pinion steering gear has a removable control valve housing surrounding the control valve and pinion shaft (Figure 12-11). In this steering gear, claw washers are used to lock the inner tie-rod ends to the rack. Apart from these minor differences, the Toyota power rack and pinion gear is similar to the Saginaw and TRW gears.

WARNING: When working on any power steering system always wear protective gloves and use caution, because the system hoses, components, and fluid can be very hot if the system has been in operation for a period of time.

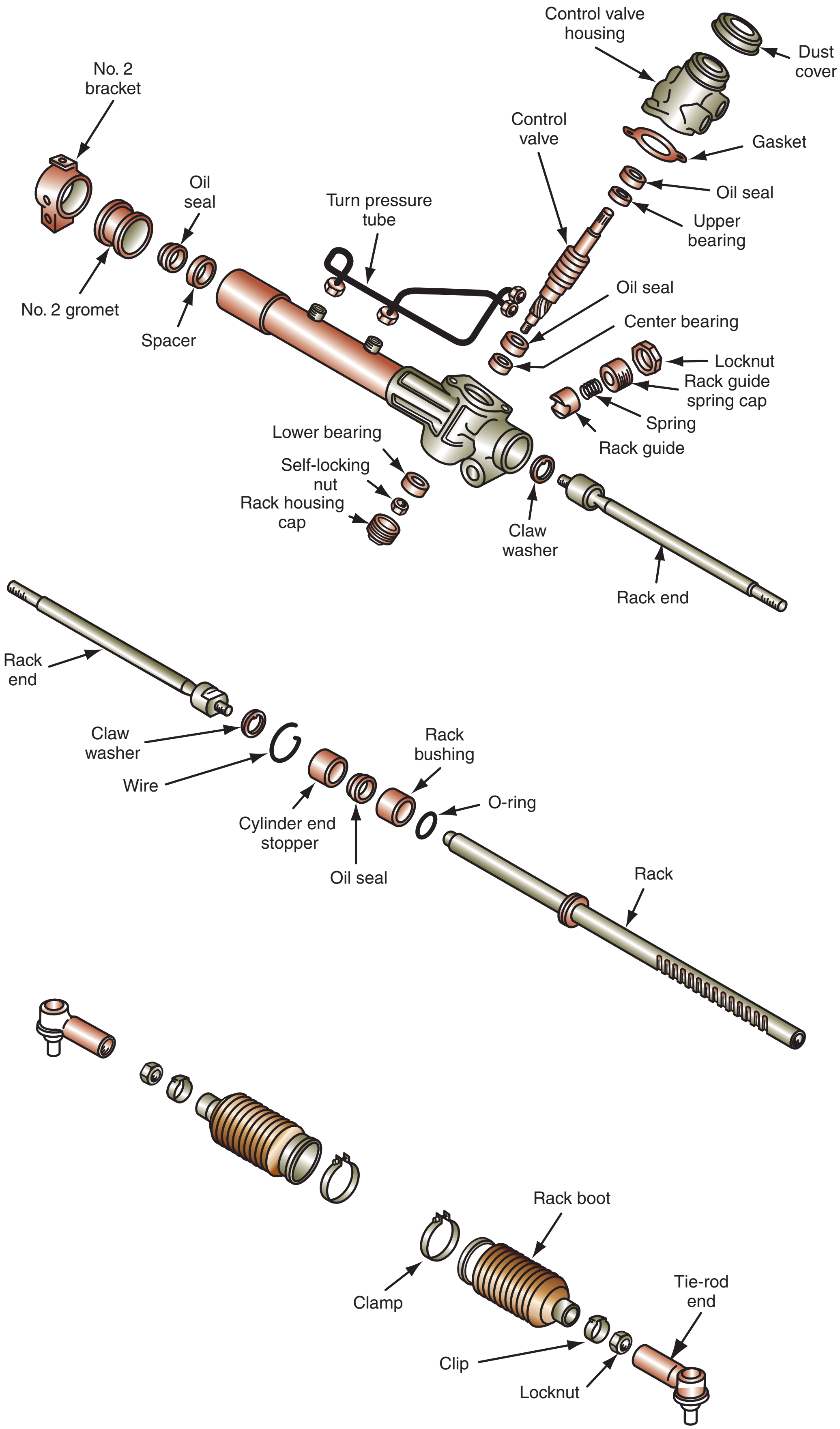

FIGURE 12-11 **Toyota power rack and pinion steering gear.**

Electronic Variable Orifice Steering

Input Sensors

The **electronic variable orifice (EVO)** steering system is standard on many late model vehicles. The EVO steering system provides high-power steering assistance during low-speed cornering and parking and normal power steering assistance at higher speeds for proper road feel. High-power steering assistance during low-speed cornering and parking increases driver convenience.

The **steering wheel rotation sensor** is mounted on the steering column, and a shutter disc attached to the steering shaft rotates through the sensor when the steering wheel is rotated. A row of slots is positioned near the outer edge of the shutter disc (Figure 12-12). When these slots rotate through the sensor, a steering wheel rotation speed signal is sent from the sensor to the control module.

The **vehicle speed sensor (VSS)** is mounted in the transaxle or transmission, and this sensor sends a signal to the control module in relation to vehicle speed (Figure 12-13). The VSS signal is also used for other purposes.

CAUTION:
Never short across, or ground, any terminals in a computer-controlled system unless you are instructed to do so in the vehicle manufacturer's service manual. Such action may damage expensive electronic components.

Control Module

On some vehicles, the control module is mounted in the trunk (Figure 12-14). This module continually monitors the input signals from the VSS and the steering wheel rotation sensor

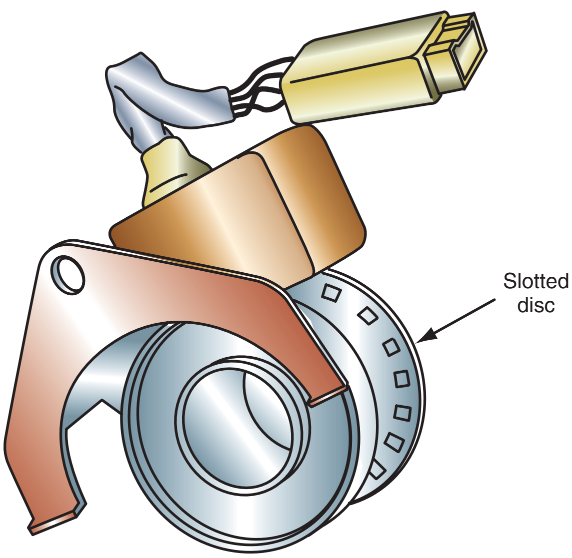

FIGURE 12-12 **Steering wheel rotation sensor.**

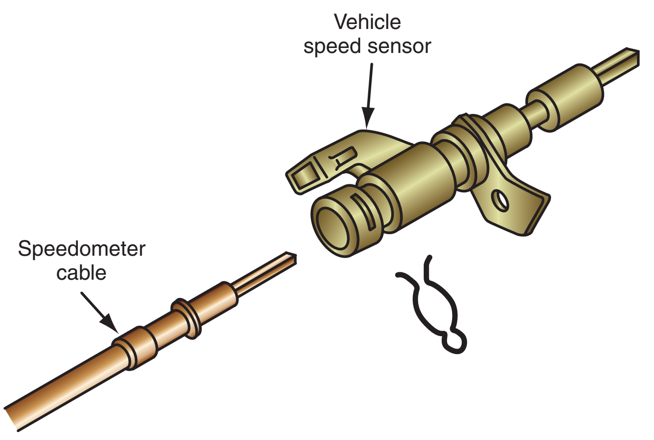

FIGURE 12-13 **Vehicle speed sensor (VSS).**

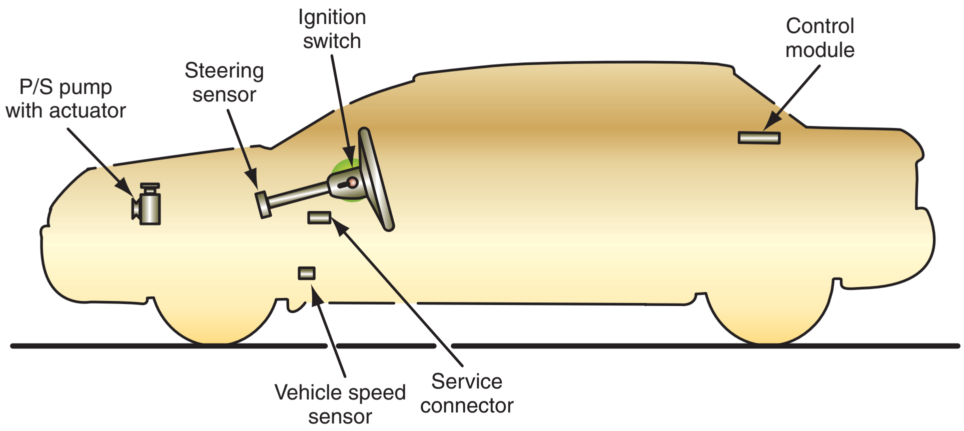

FIGURE 12-14 **Control module and main components, electronic variable orifice steering.**

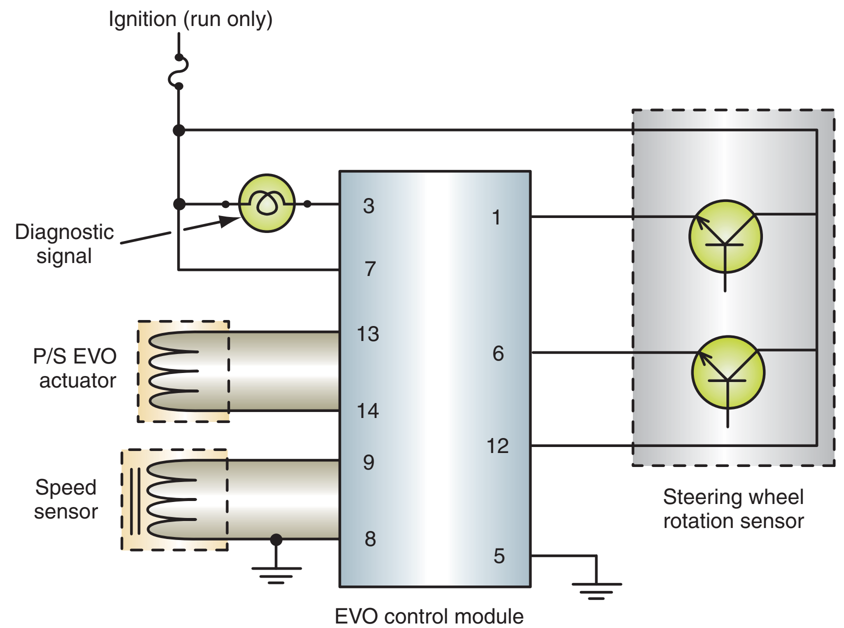

FIGURE 12-15 **Wiring diagram, electronic variable orifice steering.**

(Figure 12-15). Some models have a combined EVO steering system and rear air suspension system. On these models, the control module operates the EVO steering system and the rear air suspension system. In the combined EVO steering and rear air suspension system, the inputs and outputs from both of these systems are connected to the same control module. (The rear air suspension system is explained in Chapter 8.) If the EVO system is used alone without the air suspension system, a different control module is required.

Output Control

A varying current flow is sent from the control module through the EVO actuator in the power steering pump (Figure 12-16). The actuator swivels freely when it is installed in the power steering pump. As the control module changes the current flow through the

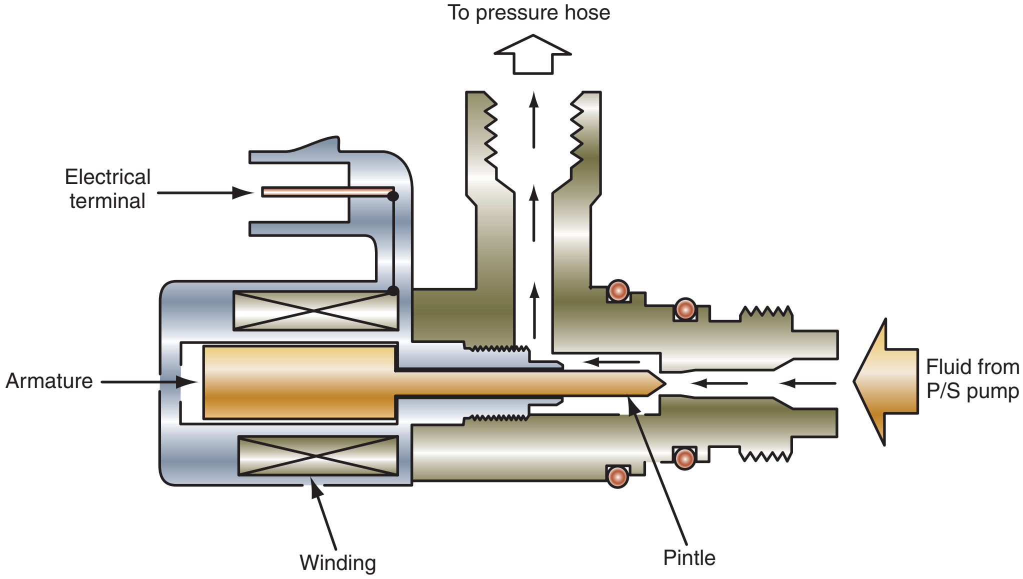

FIGURE 12-16 **Electronic variable orifice (EVO) actuator removed from the power steering pump.**

actuator, the actuator supplies a variable pressure to the spool valve in the power steering pump. Two wires are connected from the actuator to the control module. The power steering pump is mounted directly to the engine to reduce noise, vibration, and harshness (NVH).

The control module positions the actuator and spool valve to provide full power steering assistance under these conditions:

1. Vehicle speed less than 10 mph (16 km/h)
2. Steering wheel rotation above 15 rpm

The full power-assist mode reduces driver effort required to turn the steering wheel during low-speed cornering and parking for increased convenience. In the full power-assist mode, the control module supplies 30 milliamps (ma) to the actuator.

The control module positions the actuator and spool valve to reduce power steering assistance under these conditions:

1. Vehicle speed above 25 mph (40 km/h)
2. Steering wheel rotation below 15 rpm

The reduced power-assist mode provides adequate road feel for the driver. In the reduced power-assist mode, the control module supplies 300 ma to the actuator. Above 88 mph (132 km/h), 590 ma is supplied from the control module to the actuator.

Saginaw Electronic Variable Orifice Steering

Design and Operation

The term **variable effort steering (VES)** replaces the previous EVO terminology on some General Motors vehicles. In the EVO system, the vehicle speed sensor input is sent to the EVO controller. This controller supplies a pulse width modulated (PWM) voltage to the actuator solenoid in the power steering pump. The controller also provides a ground connection for the actuator solenoid (Figure 12-17).

A **pulse width modulated (PWM) voltage signal** has a variable on time.

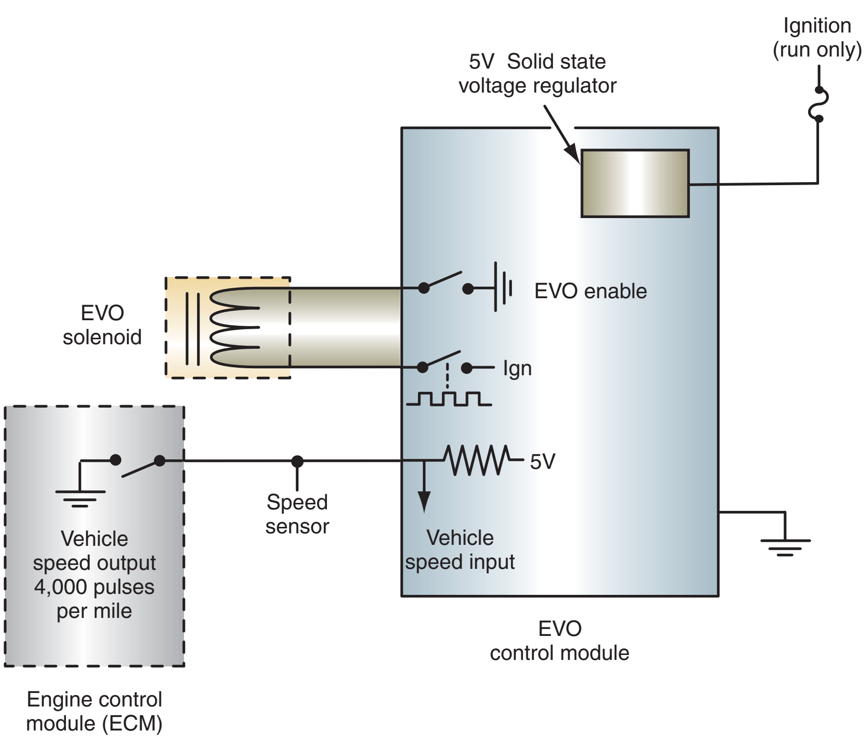

FIGURE 12-17 **Electronic variable orifice (EVO) steering system.**

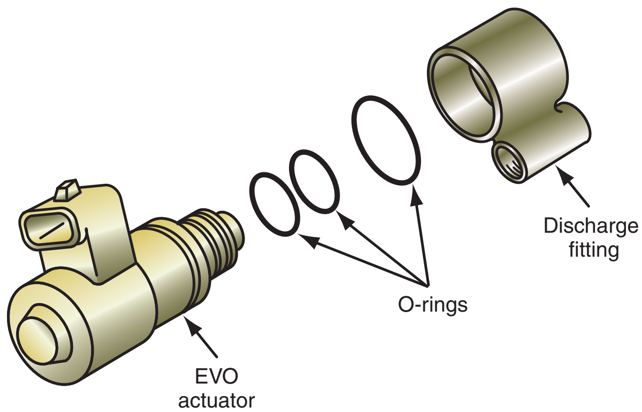

FIGURE 12-18 **Actuator solenoid.**

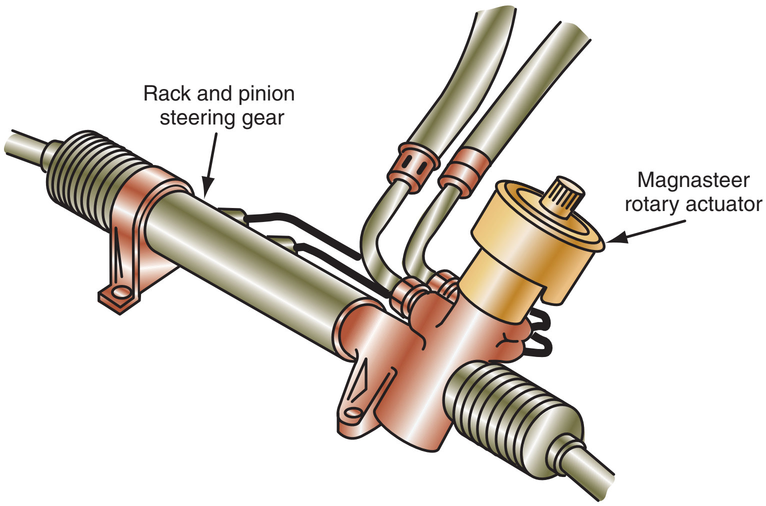

FIGURE 12-19 **Magnasteer, actuator solenoid.**

When the vehicle is operating at low speeds, the controller supplies a **pulse width modulated (PWM) voltage signal** to position the actuator solenoid plunger so the power steering pump pressure is higher (Figure 12-18). Under this condition, greater power assistance is provided for cornering or parking. If the vehicle is operating at higher speed, the controller changes the PWM signal to the actuator solenoid, and the solenoid plunger is positioned to reduce power steering pump pressure. This action reduces power steering assistance to provide improved road feel for the driver.

The **Magnasteer system** uses an actuator solenoid, a pole piece with 16 segments, and a coil in the steering gear to vary steering effort.

In a **Magnasteer system**, a bi-directional steering actuator solenoid is mounted in the steering gear (Figure 12-19). The computer that operates the Magnasteer system is combined with the electronic brake and traction control module (EBTCM), and this module is usually mounted in the left-front corner of the engine compartment (Figure 12-20). Two wires are connected from the steering actuator to the EBTCM (Figure 12-21).

The steering actuator solenoid contains a pole piece with 16 magnetic segments and a coil. A matching 16-segment permanent magnet is attached to the spool valve. As the steering wheel and the spool valve rotate, the 16 segments on the spool valve move into and out of alignment with the segments on the actuator pole piece. The EBTCM can reverse the current flow through the steering actuator, and this action reverses the magnetic poles on the actuator segments. At low vehicle speeds, the EBTCM supplies current through the steering

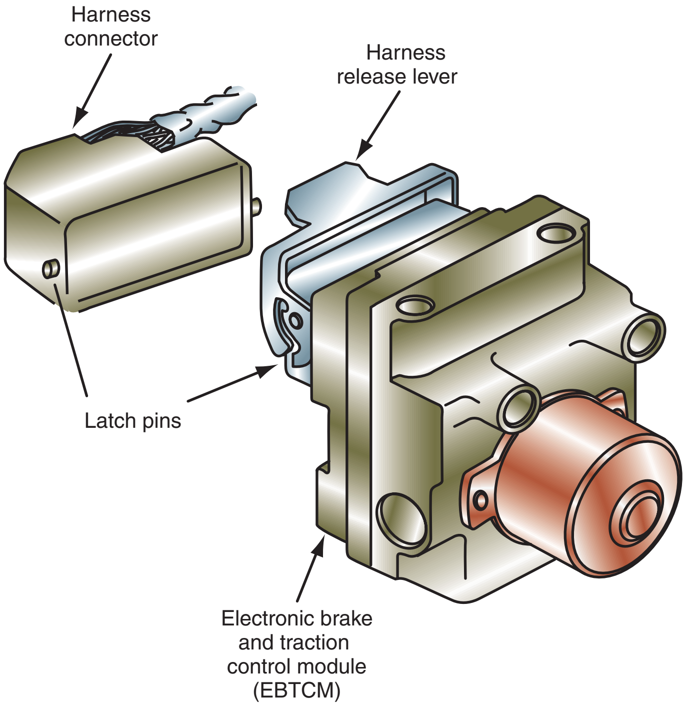

FIGURE 12-20 Electronic brake and traction control module (EBTCM).

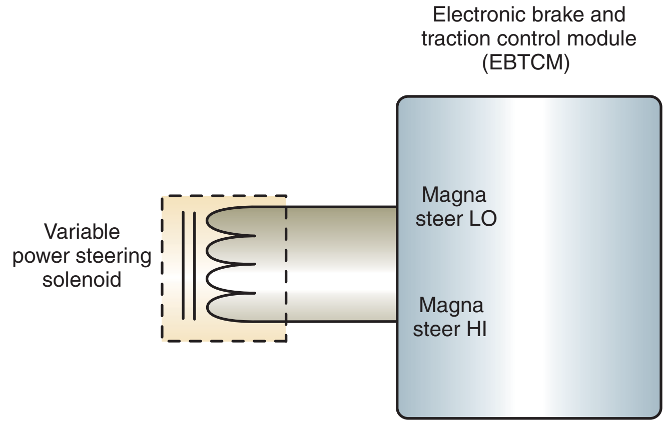

FIGURE 12-21 Wiring connections between the Magnasteer actuator solenoid and the EBTCM.

actuator so the magnetic poles on the actuator repel the permanent magnet segments on the spool valve. This repelling action assists the driver to turn the steering wheel and reduces steering effort. At higher speeds, the EBTCM reverses the current flow through the steering actuator, and this action reverses the poles on the actuator segments. Under this condition, the actuator segments are attracted to the permanent magnet segments on the spool valve. This action increases steering effort to improve driver road feel. The EBTCM also has the capability to vary the current flow through the steering actuator to provide variable steering effort in relation to vehicle speed.

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Rack-Drive Electronic Power Steering

Electronic power steering systems (EPS) may be classified as rack-drive, column-drive, or pinion-drive. All three types of EPS have a rack and pinion steering gear. In a **rack-drive EPS** the electric motor that provides steering assist is coupled to the rack in the steering gear. A **column-drive EPS** has an electric assist motor coupled to the steering shaft in the steering column, and in a **pinion-drive EPS** the electric motor is coupled to the steering gear pinion. The EPS system is light and compact compared to rack and pinion steering gear with hydraulic steering assist, because the power steering pump and hoses are not required on the EPS system. Since the EPS does not require a power steering pump driven by engine power, this system minimizes engine power loss and reduces fuel consumption. The EPS system reduces steering kickback while providing a linear steering feel.

System Components

The rack and pinion steering gear changes rotary steering wheel motion to transverse motion of the rack. The motor that provides electric steering assist is designed into the steering gear (Figure 12-22). The steering sensor is mounted in the pinion shaft. This sensor sends input voltage signals to the EPS control unit in relation to the direction, amount, and torque of the steering wheel rotation.

If the vehicle has an automatic transaxle, a VSS is mounted in the transaxle. This sensor sends voltage input signals to the transmission control module (TCM) in relation

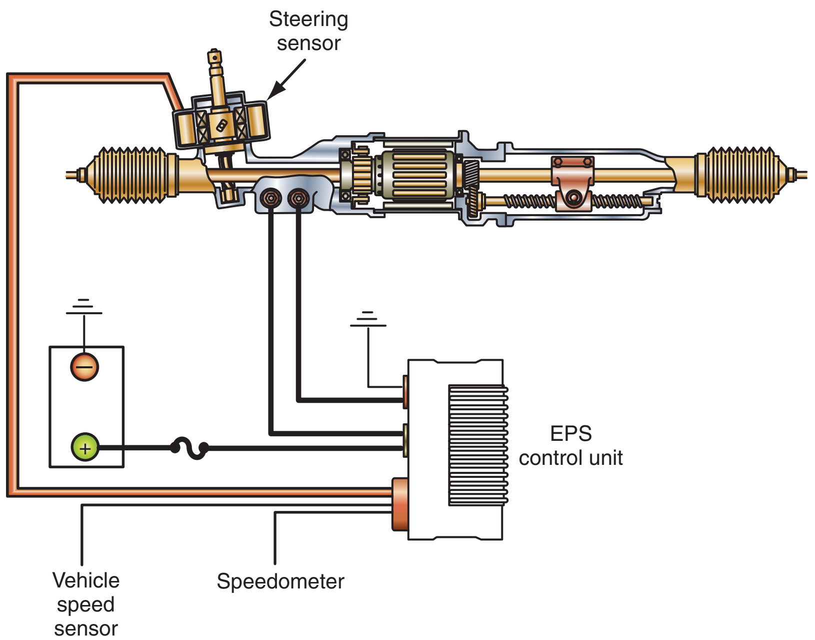

FIGURE 12-22 **Steering gear with electronic assist and related system components.**

to transaxle output shaft rotational speed. These voltage signals are transmitted from the TCM to the EPS control unit. When the car is equipped with a manual transaxle, a differential speed sensor sends voltage signals to a pulse unit in relation to differential rotational speed. These voltage signals are transmitted from the pulse unit to the EPS control unit. The TCM and pulse unit is located in the rear of the vehicle (Figure 12-23).

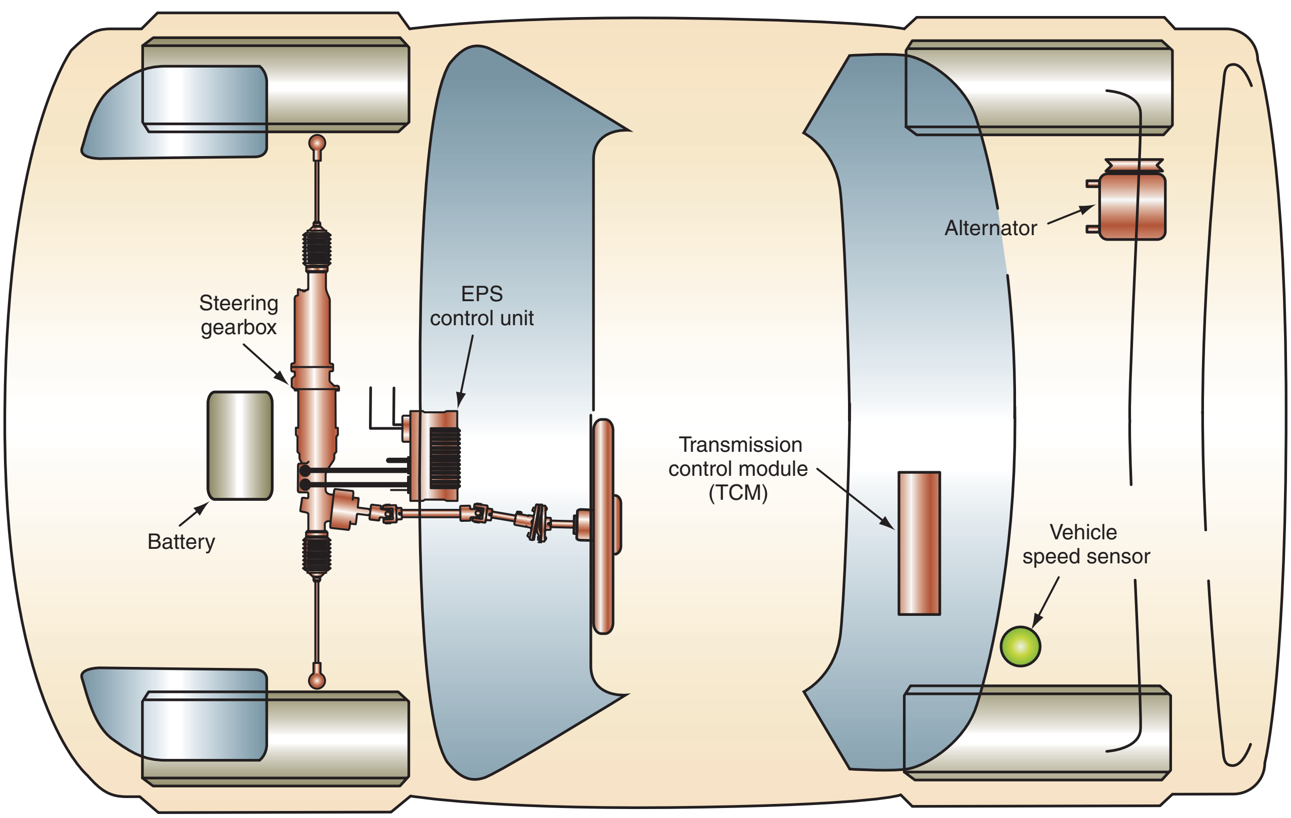

FIGURE 12-23 **Electronic power steering (EPS) system component locations.**

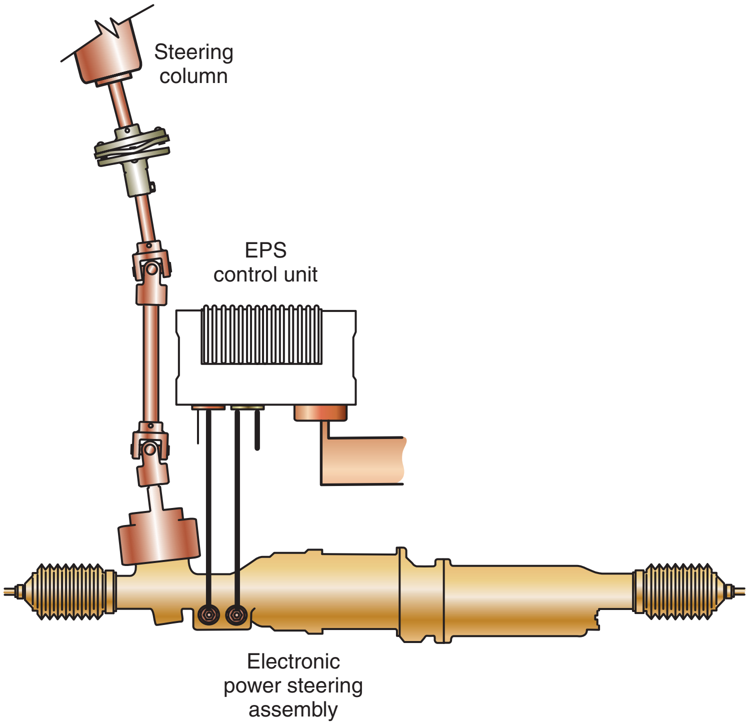

FIGURE 12-24 **Electronic power steering (EPS) control unit and steering gear.**

The speedometer also sends voltage signals to the EPS control unit. The voltage signals from the speedometer act as a double check and backup in a situation where the voltage signals from the VSS or differential speed sensor are inaccurate or nonexistent.

The EPS control unit is mounted above the steering gear (Figure 12-24). This control unit receives voltage input signals from the steering sensor, VSS, or differential speed sensor. When these signals are received, the EPS control unit calculates the proper amount and direction of steering assist. The EPS control unit then commands a power module in the EPS control unit to drive the electric motor in the steering gear and provide the proper direction and amount of steering assist. The EPS control unit also contains self-diagnostic capabilities.

Electronic Power Steering System Operation

Steering Sensor

The steering sensor contains a torque sensor and an interface. This sensor contains a slider core mounted on the pinion shaft. A spiral groove is located in each side of the slider, and two pins protruding from the pinion shaft are positioned in these grooves. The slider turns with the pinion shaft. When there is very little resistance to front wheel turning, the slider and pinion shaft rotate together and the pins remain centered in the spiral grooves in the slider. Very little resistance to front wheel turning occurs if the front tires are on a slippery road surface, or if the vehicle is raised so the front tires are off the floor. When there is resistance to front wheel turning, the torsion bar twists in the pinion shaft. This action causes the pins to move in the slider spiral grooves, and this movement causes upward or downward slider movement (Figure 12-25).

The slider core is surrounded by a variable differential transformer, and the slider moves upward or downward inside the transformer windings when the steering wheel is turned (Figure 12-26). The transformer has a primary coil and upper and lower secondary coils. When the ignition switch is turned on, an oscillation circuit in the steering sensor supplies an alternating current to the primary transformer coil. As the current alternates back and

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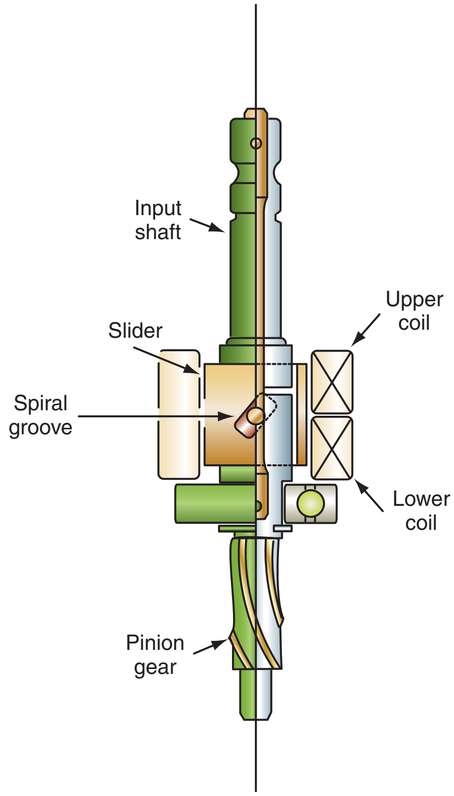


FIGURE 12-25 **Pinion shaft with slider and variable differential transformer.**

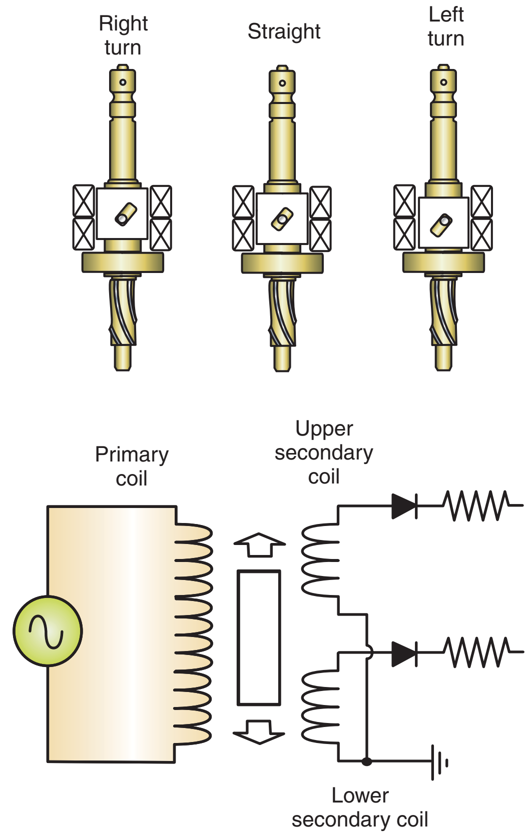


FIGURE 12-26 **Slider movement when turning the steering wheel.**

forth through the primary coil, the magnetic field is continually building up and collapsing around this coil. This rapidly expanding and collapsing magnetic field induces voltages in the upper and lower secondary coils. The position of the slider determines whether the voltage is induced in the upper or lower secondary coil.

While driving straight ahead, the slider is centered vertically between the upper and lower secondary coils. Under this condition, the voltage induced in these coils is equal. When voltages are equal in the upper and lower secondary coils, the voltage signals from these coils to the EPS control unit indicate the car is being driven straight ahead, or the steering wheel is being turned with no resistance and no electric power assist is required.

If the steering wheel is turned to the right, the slider moves upward. This slider position causes more induced voltage in the upper secondary coil and less induced voltage in the lower secondary coil. When these voltage signals from the upper secondary coil are sent to the EPS control unit, this control unit supplies current to the electric motor on the rack so the motor rotates in the appropriate direction to provide the proper amount of steering assist to the right (Figure 12-26).

When the steering wheel is turned to the left, the slider moves downward. This slider position causes more induced voltage in the lower secondary coil and less induced voltage in the upper secondary coil. When these voltage signals from the lower secondary coil are sent to the EPS control unit, the control unit supplies current to the electric motor on the rack so the motor rotates in the appropriate direction to provide the proper amount of steering assist to the left (Figure 12-27).

The voltage signals from the upper and lower secondary transformer coils are sent through the interface in the steering sensor to the EPS control unit (Figure 12-28). The interface rectifies the alternating current (AC) voltage signals from the upper and lower transformer coils to direct current (DC) voltage signals and amplifies or increases the signal strength.

Steering condition	Slider movement	Induction voltage on secondary coil
Steering to right (load steering)	Upward shift	Voltage on upper coil increases, and voltage on the lower decreases
Advancing straight ahead (no load steering)	Neutral	Voltage on the upper and lower coils are equal
Steering to left (load steering)	Downward shift	Voltage on lower coil increases, and voltage on the upper decreases

FIGURE 12-27 **Summary of steering sensor and transformer operation.**

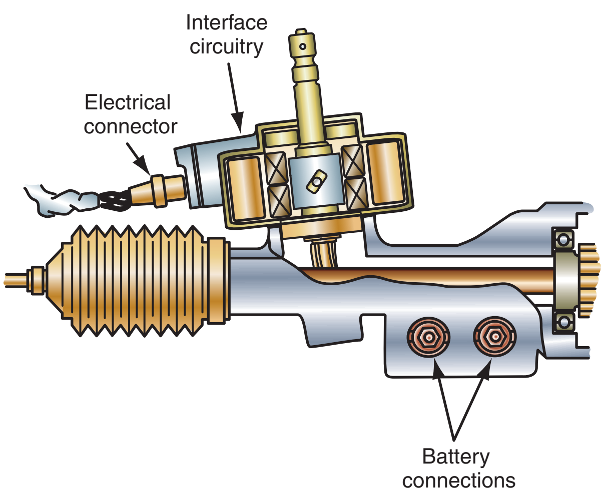


FIGURE 12-28 **Interface in the steering sensor.**

Electric Motor and Steering Gear Operation

The armature in the electric motor is hollow, and the rack extends through the center of this armature. Ball bearings are mounted between the outer diameter of the armature and the steering gear housing to support the armature. Two spring-loaded brushes are mounted on opposite sides of the commutator on one end of the armature. A gear with helical teeth is mounted on the other end of the armature. The teeth on the armature gear are in constant mesh with a matching gear on the ball screw shaft (Figure 12-29). A recirculating ball screw nut is mounted on the ball screw shaft. Ball bearings are mounted in grooves in the ball screw shaft and recirculating ball screw nut. The recirculating ball screw is bolted to the steering gear rack. The ball screw shaft and recirculating ball screw nut are similar in design to the worm shaft and ball nut in a recirculating ball steering gear. A permanent magnet is mounted in the steering gear housing, and this magnet surrounds the armature core. There is a small clearance between the armature core and the permanent magnet.

When the steering wheel is turned, electric current is supplied from the power module in the EPS control unit through the brushes and armature windings to ground. This current flow creates strong magnetic fields around the armature windings. These magnetic fields around the armature windings react with the magnetic field of the permanent magnet and cause armature rotation in the proper direction to supply steering assist. When the armature rotates, the gear on the armature shaft drives the gear on the ball screw shaft. Ball screw

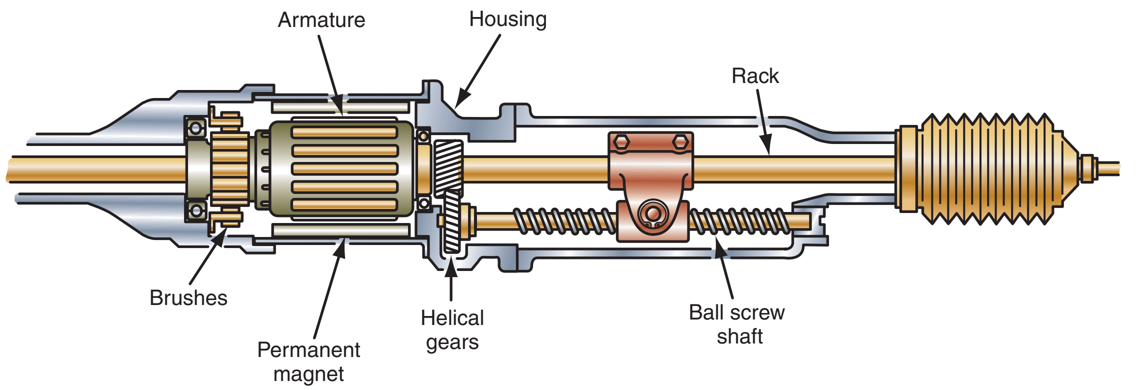


FIGURE 12-29 **Steering gear and electric motor.**

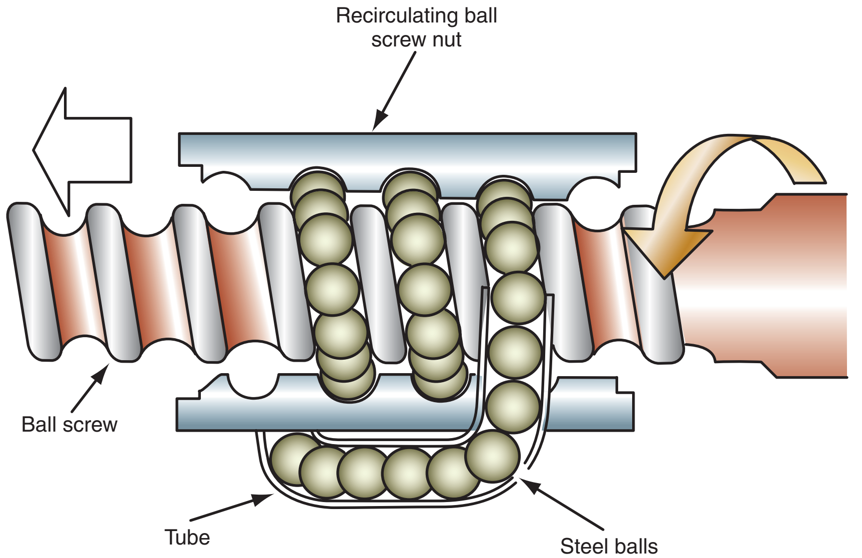


FIGURE 12-30 **Ball screw shaft and recirculating ball screw nut.**

shaft rotation moves the recirculating ball screw nut on the shaft. Since the recirculating ball screw nut is bolted to the steering gear rack, movement of this ball screw nut provides steering assist in the proper direction. The power module can reverse the armature rotation to provide steering assist in either direction by reversing the polarity of the brushes on the commutator. When the brush polarity is reversed, the current flow through the armature windings is reversed and this changes the direction of armature rotation.

The recirculating ball screw nut is designed so the ball bearings roll between the grooves in the ball screw shaft and the grooves in the recirculating ball screw nut. Ball bearings coming out of the recirculating ball screw nut move through a tube and re-enter the recirculating ball screw nut at the other end (Figure 12-30). The ball bearings in the grooves in the ball screw shaft and recirculating ball screw nut allow this nut to move on the shaft with very low friction.

Steering Gear Motor Current Control

The power module in the EPC control unit contains a driving circuit, current sensor, field effect transistor (FET) drive circuit, power relay, and fail safe relay. When the ignition switch is turned on and the engine is cranked, the EPS control unit closes the power relay and fail safe relay to make the EPS system operational. These relays actually close when the alternator begins producing voltage while the engine is cranking. Voltage signals are sent from the alternator and the ignition switch to the EPS control unit (Figures 12-31 and 12-32). The EPS

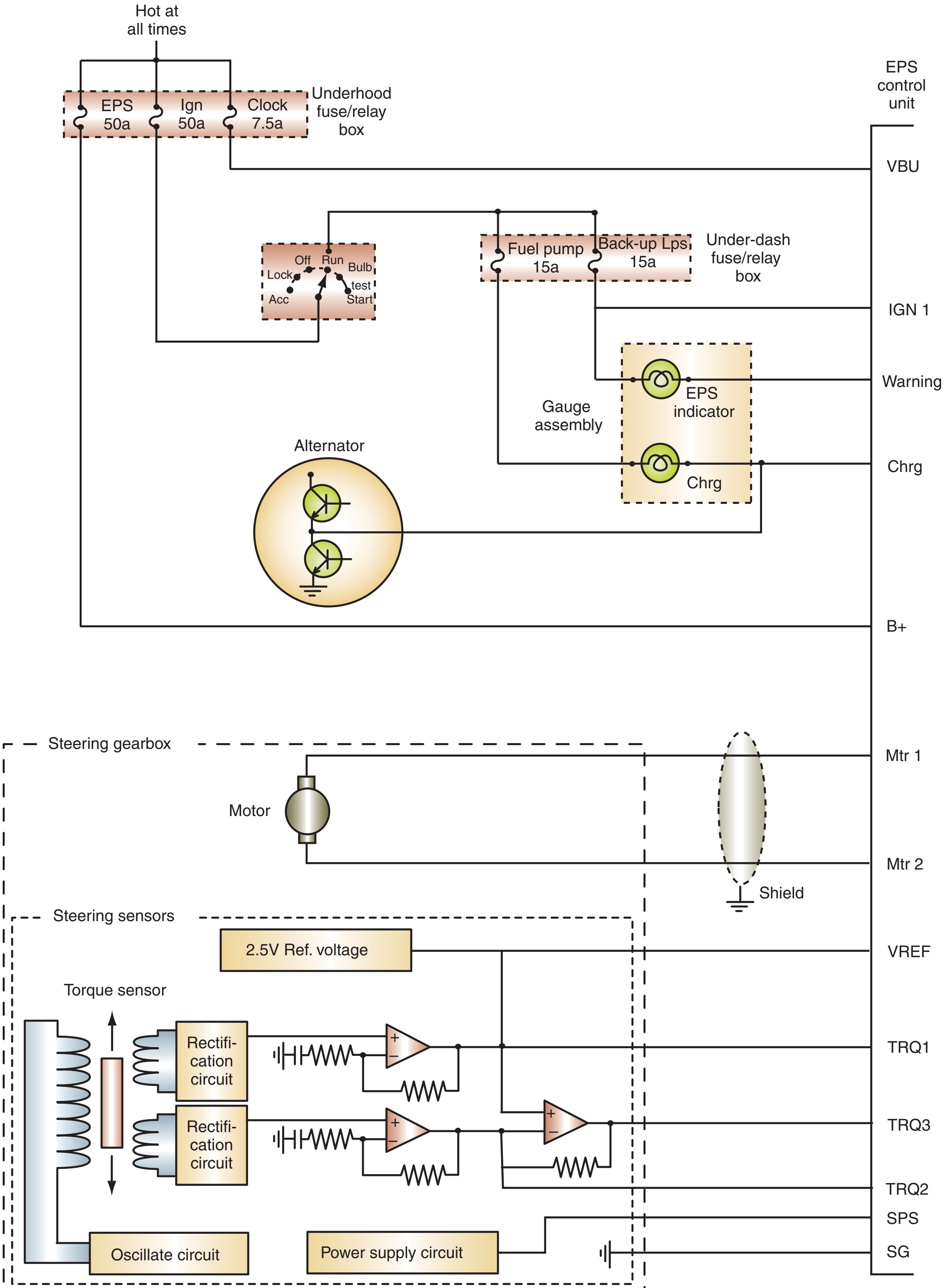


FIGURE 12-31 **EPS system wiring diagram.**

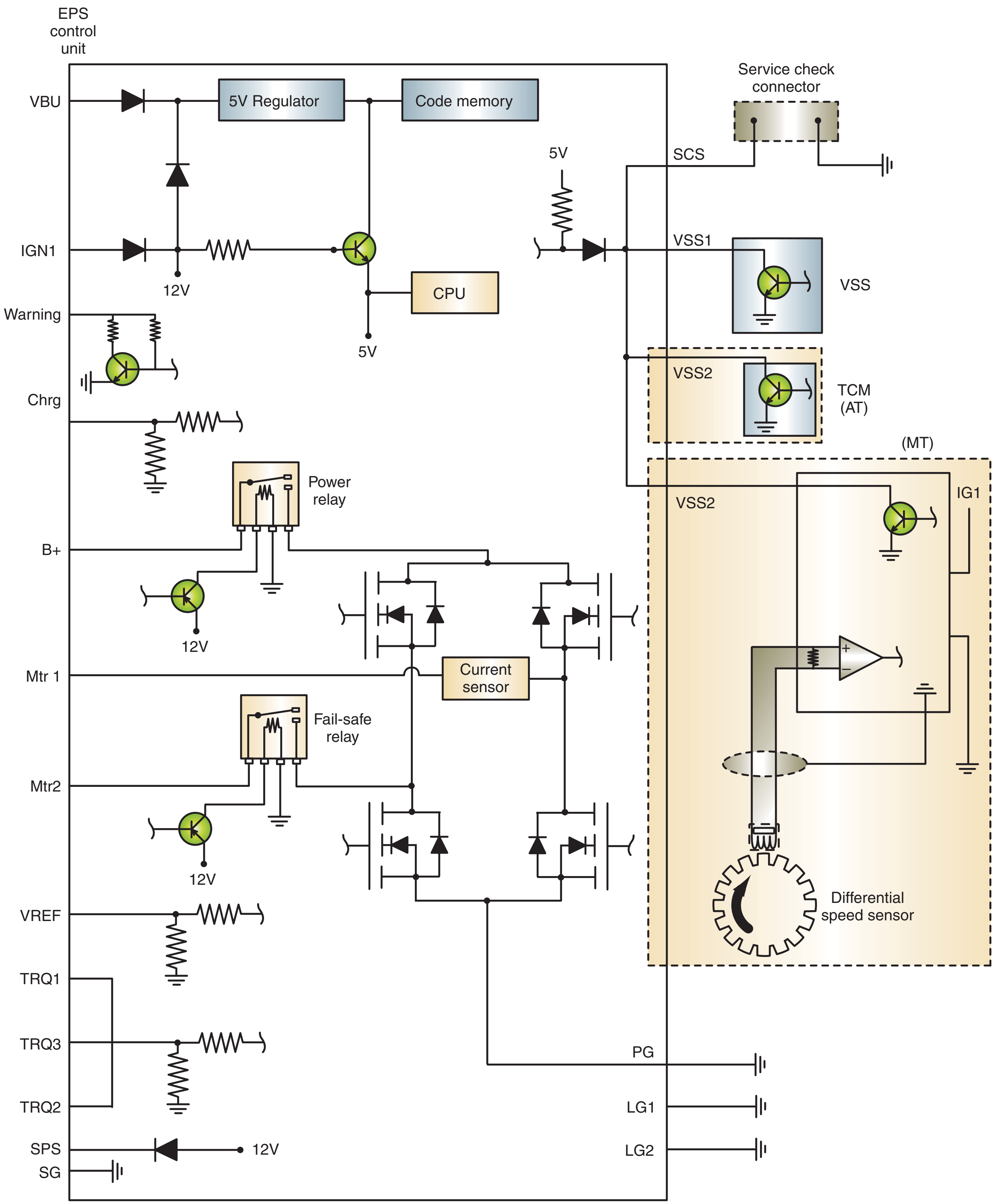


FIGURE 12-32 **EPS system wiring diagram (continued).**

system remains operational if the engine stalls and the ignition switch is on. If the engine stalls on a hydraulically assisted power steering system, power steering assist is lost and the steering wheel becomes very hard to turn. This action may result in a collision if the engine stalls while turning a corner. Since the EPS system is still operational if the engine stalls and the ignition switch is on, the EPS system reduces the possibility of a collision resulting from loss of power steering assist during an engine stall.

When the driver turns the steering wheel, the steering sensor input voltage signals inform the EPS control unit that steering assist is necessary. The steering sensor input voltage signals also inform the EPS control unit regarding the direction and amount of steering assist required. If the driver supplies more torque to the steering wheel, the steering sensor input voltage signal indicates to the EPS control unit that more steering assist is necessary.

When the EPS control unit receives input voltage signals from the steering sensor indicating that steering assist is required, this control unit signals the FET drive circuit in the power module. This drive circuit supplies a pulse width modulated (PWM) voltage to the motor brushes with the proper polarity to provide the required direction and amount of steering assist. A PWM voltage signal is a pulsating voltage signal with a constant frequency but has a variable on time. One cycle of a PWM signal is a specific length of time that includes one Off and one On signal. If the on time lasts for 40 percent of each cycle time and the off time lasts for 60 percent of the cycle time, the motor current remains lower and this reduces motor speed and steering assist. When the on time lasts for 60 percent of each cycle time, and the off time lasts for 40 percent of the cycle time, the motor current is higher and power steering assist is increased (Figure 12-33). The FET drive circuit operates the four FET transistors in the FET bridge to supply the proper direction and amount of voltage and current

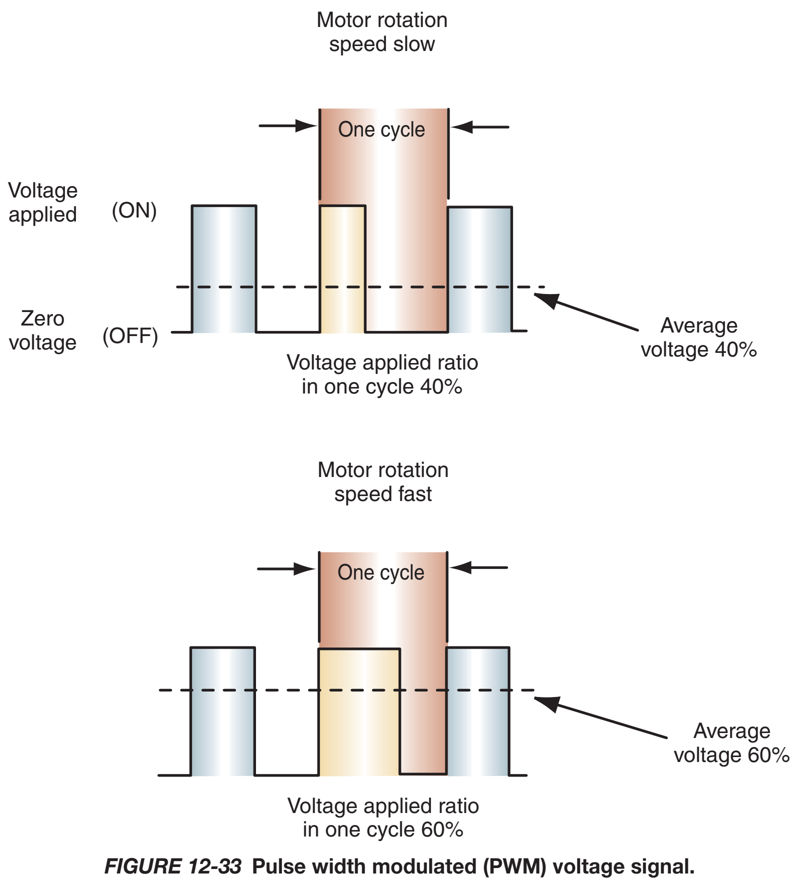
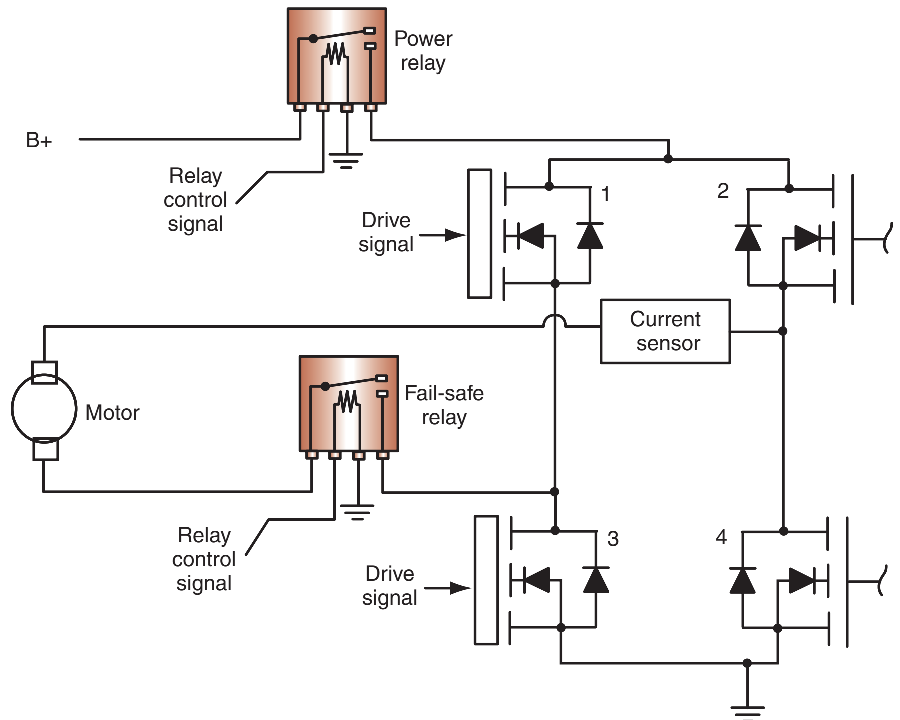


FIGURE 12-33 **Pulse width modulated (PWM) voltage signal.**



Steering condition	FET (1)	FET (2)	FET (3)	FET (4)	Motor operation
Steering to right	PWM	OFF	OFF	ON	Operates in direction steering to the right
Straight ahead	OFF	OFF	OFF	OFF	Stops
Steering to left	OFF	PWM	ON	OFF	Operates in direction steering to the left

FIGURE 12-34 **Drive circuit and field effect transistor (FET) bridge in the power module.**

through the armature windings to provide the necessary direction and amount of steering assist (Figure 12-34).

While the electric assist motor is operating, the motor current flows through a current sensor in the power module regardless of the direction of motor rotation. The current sensor sends a feedback voltage signal to the EPS control unit. If the motor current exceeds a predetermined average motor current for the current operating condition, the EPS control unit signals the drive circuit in the power module to reduce the motor current to prevent motor overheating. If the steering wheel is turned fully in one direction and held in this position, the motor current becomes much higher. Under this condition, the current sensor signals the EPS control unit, and this unit signals the drive circuit in the power module to reduce motor current to protect the motor.

If an electrical defect occurs in the EPS system, the EPS control unit illuminates an EPS indicator light in the instrument panel to inform the driver that a fault is present in the EPS system (Figure 12-35). Under this condition, the EPS unit opens the fail safe and power relays to make the EPS system inoperative. When this action occurs, manual steering without any power assist is available.

If one of the front wheels strikes a large road irregularity, force from the front wheel is transferred to the steering gear rack. Rack movement attempts to move the ball screw nut on

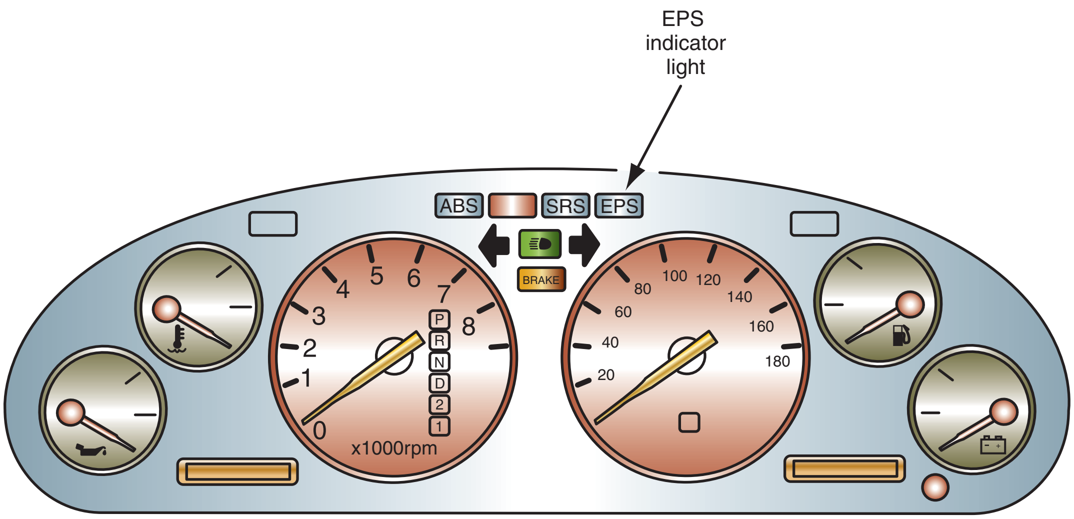


FIGURE 12-35 **EPS indicator light.**

the ball screw shaft. This action tries to rotate the ball screw shaft and armature. A specific amount of force is required to move the ball screw nut and rotate the ball screw shaft and armature because the armature windings have to rotate through the magnetic field between the permanent magnets. This resistance to movement of the ball screw nut, ball screw shaft, and armature helps prevent road shock from being supplied through the steering gear to the steering wheel. When a very high road shock is transferred to the steering wheel, this road shock moves the pinion shaft and slider in the steering sensor. When this EPS control unit receives this steering sensor input signal, the EPS control unit immediately energizes the armature windings to oppose and cancel the road shock applied to the steering gear. Therefore, the EPS steering gear reduces road shock transferred from the front wheels to the steering wheel.

Column-Drive Electronic Power Steering

Some vehicles are presently equipped with a column-drive EPS. In this type of EPS, a motor/module assembly is bolted to the lower end of the steering column (Figure 12-36). A combined steering wheel position sensor and steering shaft torque sensor is mounted in the steering column at the motor/module attachment point. The module in the motor/module assembly is called the power steering control module (PSCM). Mounting the EPS motor/module assembly under the instrument panel provides underhood space for other components, subjects the assembly to less rigorous temperatures, and may provide better protection during a collision.

Input Sensors

The steering shaft torque sensor is the most important input used by the PSCM to supply the proper amount and direction of steering assist. The steering column contains a torque sensor input shaft connected from the steering wheel to the sensor, and an output shaft connected from the sensor to the steering shaft coupler. A torsion bar mounted inside the steering shaft torque sensor separates the input and output shafts. When the steering wheel is turned in either direction, the torque supplied from the steering wheel to the torsion bar causes this bar to twist. Increased torsion bar twisting results in higher voltage signals from the steering shaft torque and position sensors. The steering shaft torque sensor is a dual sensor that provides two different voltage signals (Figure 12-37). During a right turn the voltage from sensor 1 increases and the voltage from sensor 2 decreases. The voltage signal range from each sensor is 0.25 V to 4.75 V. While completing a left turn, the voltage from sensor 1 decreases and the

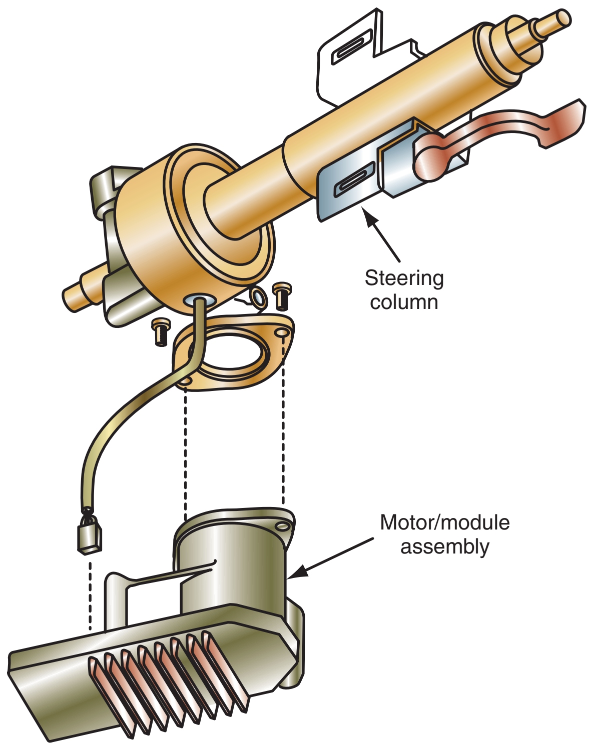


FIGURE 12-36 **Column-drive electronic power steering system.**

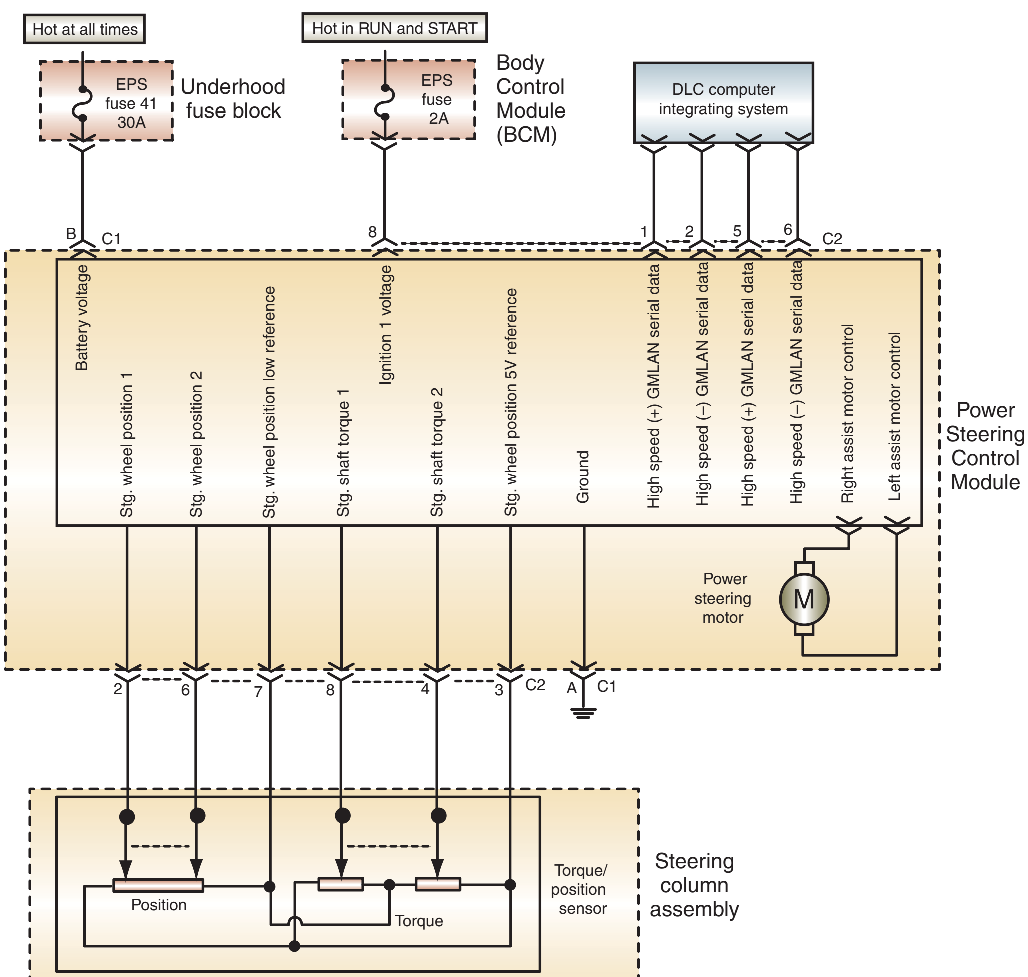


FIGURE 12-37 **Wiring diagram for column-drive electronic power steering.**

voltage from sensor 2 increases. The steering shaft torque sensor voltage signals inform the PSCM regarding the direction and amount of steering wheel torque.

The steering wheel position sensor also contains dual voltage sensors that operate in the 0 V–5 V range. During steering wheel rotation the voltage from these two sensors should remain within 2.5 V–2.8 V of each other. The steering wheel position sensor informs the PSCM regarding the position of the steering wheel. The combined steering shaft torque and position sensor assembly is serviced only as a unit.

The PSCM also receives a vehicle speed input signal from the powertrain control module (PCM). This voltage signal is transmitted from the PCM to the PSCM through the interconnecting data links.

Power Steering Motor

The power steering motor is a 12 V brushless DC reversible motor rated at 65 amperes. This motor is coupled to the steering shaft through a worm gear and reduction gear located in the steering column housing.

Column-Drive Electronic Power Steering Operation

When the input signals indicate the driver is beginning to turn the steering wheel, the PSCM supplies the proper amount of current to the power steering motor to provide the necessary power steering assist. At low vehicle speeds the PSCM provides more steering assist for easy steering wheel rotation during parking maneuvers. The PSCM reduces the motor current and provides reduced steering assist when the vehicle is driven at higher speeds to supply improved road feel and directional stability. If the EPS motor becomes overheated, the PSCM enters a protection mode that reduces motor current to avoid thermal damage to system components. The PSCM has the capability to detect electronic system defects in the EPS system. When a defect is detected, a POWER STEERING warning message is displayed in the driver information center (DIC) in the instrument panel and the malfunction light (MIL) may also illuminate. The PSCM must be programmed with the correct steering tuning in relation to the vehicle powertrain configuration.

Pinion-Drive Electronic Power Steering

Some hybrid vehicles are equipped with a 12 V EPS, because on these vehicles the engine is automatically shut off during idle operation to conserve fuel and reduce emissions, and the power steering remains operational when the engine is stopped. The EPS also conserves fuel because it is used on demand only when the driver turns the steering wheel. On conventional hydraulic power steering systems the power steering pump operates all the time the engine is running. Some current hybrid vehicles have a pinion-drive EPS. The electric motor on the EPS is coupled to the pinion in the rack and pinion steering gear (Figure 12-38). Except for the drive motor and related drive gears, the other components in the EPS are conventional in design. The EPS is lubricated for life and has no reservoir, fluid, or hoses.

The EPS contains an electromagnetic-type rotational sensor mounted in the steering gear input shaft. This rotational sensor changes a rotational signal to a voltage signal representing the direction and amount of torque supplied from the steering wheel to the input shaft. The power steering control module (PSCM) is mounted on the cowl above the steering gear. The PSCM is interconnected to other on-board computers through the data link system. Additional inputs such as vehicle speed are transmitted from the PCM through the data links to the PSCM. When the PSCM receives input signals from the rotational sensor and the PCM, the PSCM supplies the proper amount and direction of current flow to the electric motor in the EPS to provide the required steering assist. A drain wire is connected from the PSCM to ground. This wire prevents the EPS from emitting electromagnetic interference that could affect other electrical/electronic systems in the vehicle. If a defect occurs in the EPS electrical system, a SERVICE PWR STEERING message illuminates in the instrument panel.

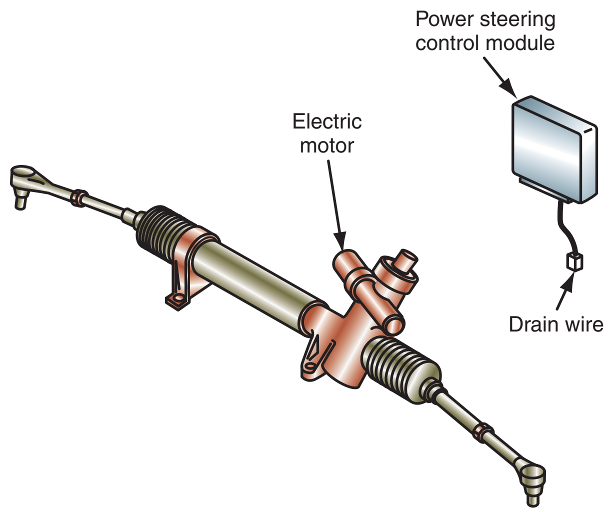


FIGURE 12-38 **Pinion-drive electronic power steering (EPS) steering gear.**

Active Steering Systems

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Active steering is available on a number of luxury vehicles. An active steering system contains many of the same components located in a conventional power rack and pinion steering system. The main difference in the active steering system is that the steering wheel and steering shaft are no longer connected directly to the pinion gear in the steering gear. In an active steering system, a dual planetary gear set is connected between the steering shaft and the pinion gear in the steering gear (Figure 12-39). The steering wheel and shaft are connected

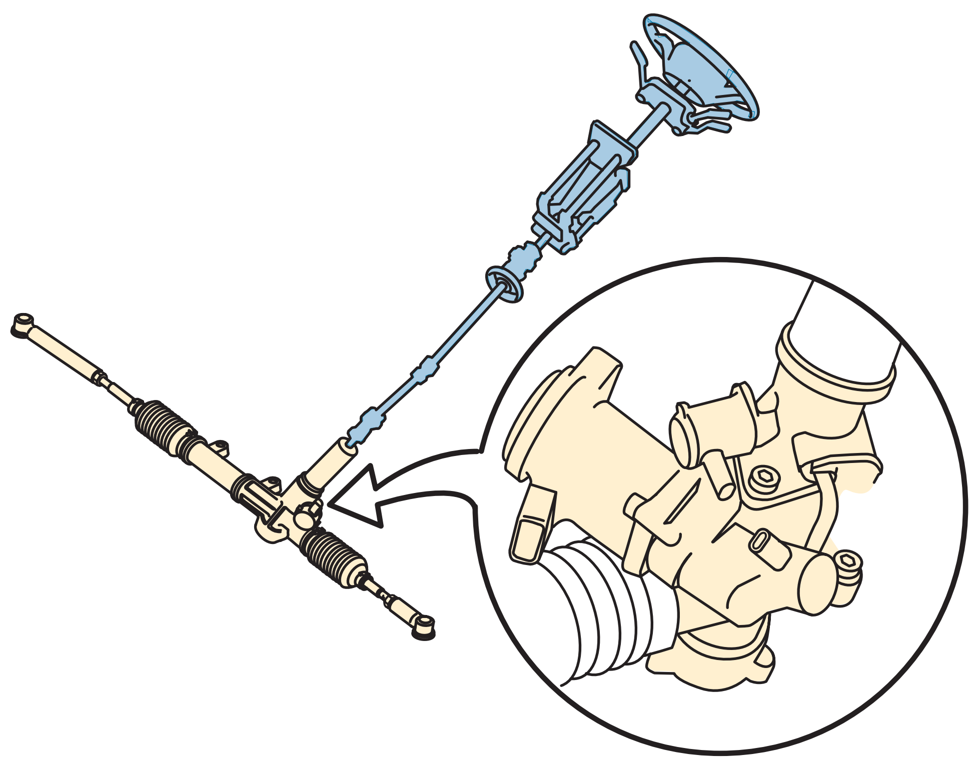


FIGURE 12-39 **Active steering system.**

to one of the sun gears in a dual planetary gear set. The second sun gear in the planetary gear set is connected to the pinion gear in the steering gear. The two sun gears are connected by a set of planetary pinions. A brushless 3-phase DC electric motor drives the ring gear on the planetary gear sets through a worm drive (Figure 12-40).

The **electronic control unit (ECU)** operates the electric motor to control the steering gear ratio and provide steering angle corrections to improve vehicle stability (Figure 12-41). In the active steering system, there is always a mechanical connection between the steering

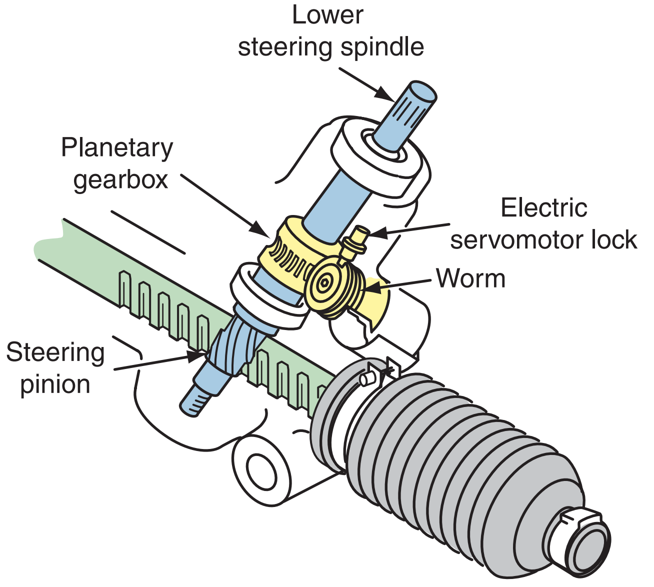


FIGURE 12-40 **Active steering actuator.**

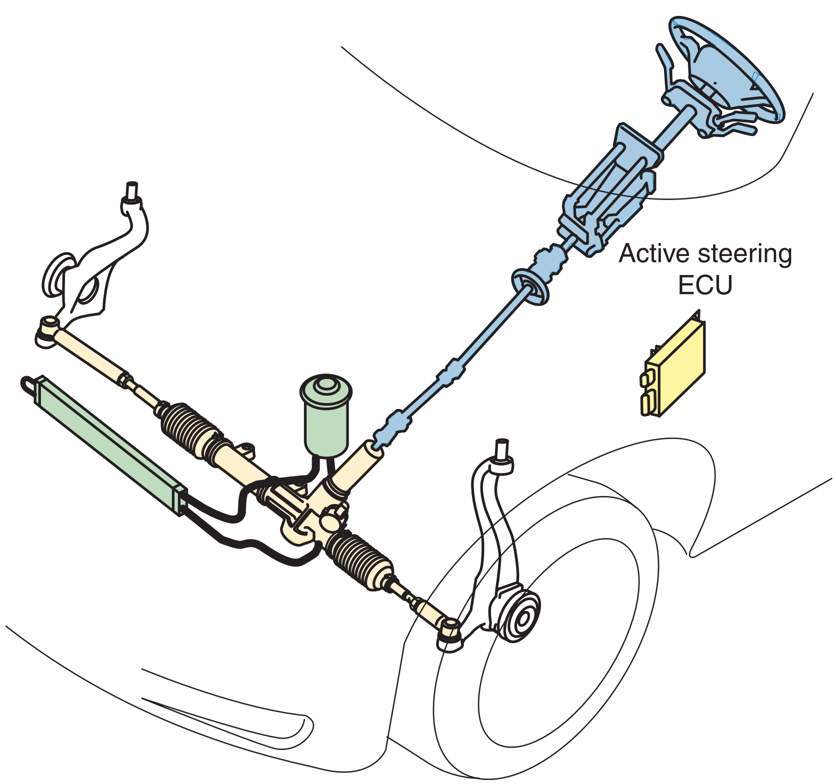


FIGURE 12-41 **Active steering ECU.**

wheel and the pinion gear in the steering gear. The ECU may drive the electric motor and change the steering gear ratio or steering angle, but the mechanical connection between the steering wheel and the steering gear pinion always leaves the driver in control of the steering. The electric motor in the active steering system never provides turning forces to the front wheels.

Active Steering System Components

DC Electric Motor and Motor Position Sensor

The electric drive motor has a wound stator and a permanent magnet rotor assembly. The ECU controls drive motor torque by a field-orientated control. The motor position sensor is mounted in the end of the electric motor, and this sensor informs the ECU regarding electric motor position.

Steering Angle Sensor

The **steering angle sensor** is mounted in the steering column switch assembly. The steering angle sensor is an optical sensor with no contacting parts, and this sensor is mounted to the circuit board near the top of the steering column (Figure 12-42). The main components in the steering angle sensor are an **encoded disc** and an optical sensor. The encoded disc is attached to the steering shaft and rotates with this shaft. The encoded disc rotates within the optical sensor (Figure 12-43). The stationary part of the steering angle sensor contains a light-emitting diode (LED), fiber-optical conductor, and a line camera. When the sensor is operating, light from the LED is projected onto the encoded disc through the optical conductor. As the steering wheel is rotated, varying amounts of light from the LED will penetrate the encoded disc and shine on the line camera. The line camera converts these light signals to voltage signals in relation to steering wheel rotation. The type of sensors in an active steering system may vary depending on the model and year of vehicle.

Pinion Angle Sensor and Summation Sensor

The **pinion angle sensor** is mounted in the steering gear at the end of the pinion housing, and this sensor operates on a magneto-resistive principle. The pinion angle sensor sends a signal to the ECU regarding pinion position. The **summation sensor** is mounted in the steering gear housing, and this sensor sends a signal to the ECU in relation to total steering gear rack movement.

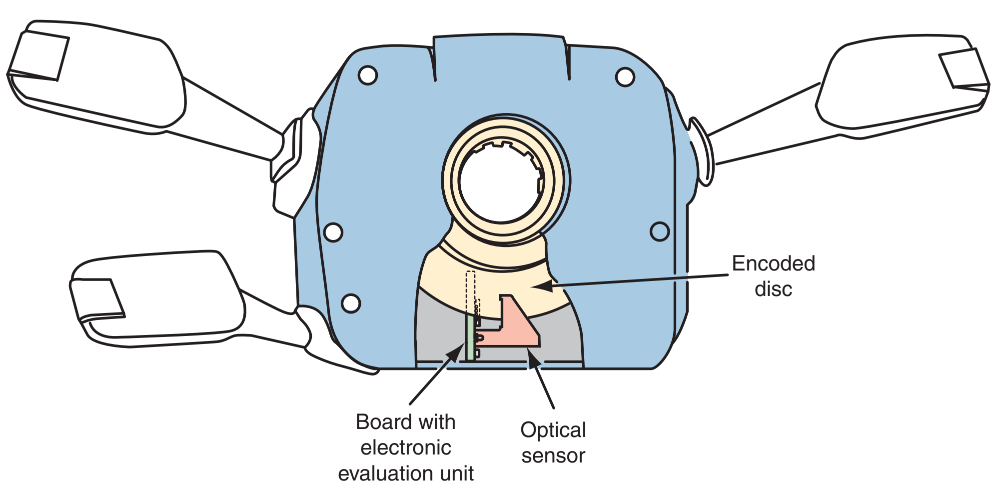


FIGURE 12-42 **Steering angle sensor mounting.**

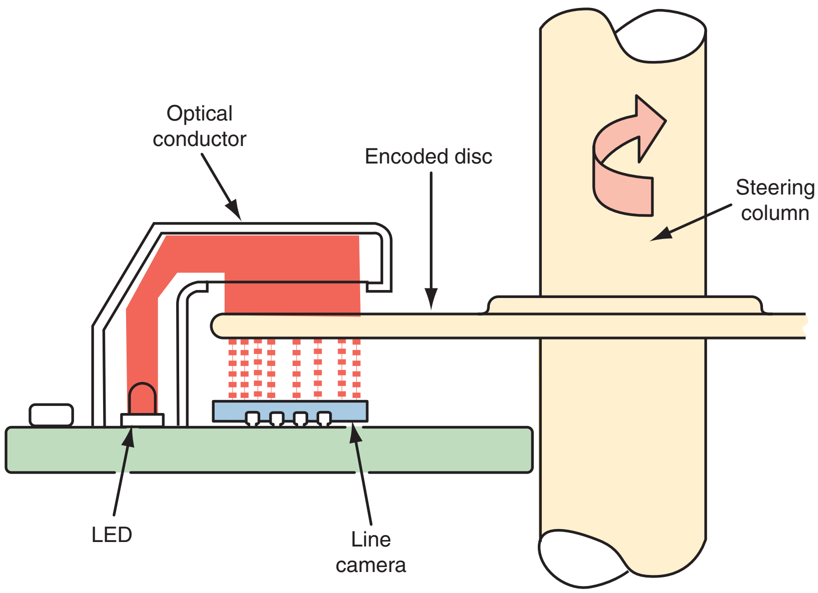


FIGURE 12-43 **Steering angle sensor internal design.**

Electronic Control Unit (ECU)

The ECU contains two microprocessors that control the electric motor, steering pump, servotronic valve, and electric locking unit. The ECU communicates with other ECUs and the active steering system input sensors via a CAN network.

Electric Locking Unit (ELU)

The **electric locking unit (ELU)** contains an electric solenoid and a lock pin. When the ELU solenoid is not energized by the ECU, the lock pin drops into one of the slots in the worm drive gear. This action locks the worm drive and drive motor (Figure 12-44). This locking action is taken by the ECU if a safety-related defect occurs in the active steering system. When the worm drive is locked, the driver maintains normal steering control. Under normal conditions, the ECU operates the ELU solenoid and pulls the lock pin away from the notches in the worm drive gear, and this allows normal active steering system operation.

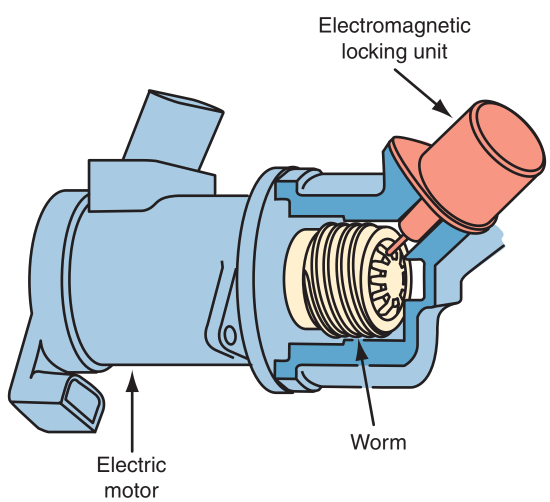


FIGURE 12-44 **Actuator motor locking mechanism.**

Active Steering Operation

The actuator motor and planetary gear set have the capability to vary the steering gear ratio in relation to vehicle speed. The ECU receives voltage input signals from the system sensors, and in relation to these inputs, the ECU operates the actuator motor to vary the steering gear ratio. While cornering at low speeds, the steering gear ratio approximates 10:1. With this ratio, the driver does not have to rotate the steering wheel as much to obtain more front wheel turning action. When the vehicle is stationary, less than two steering wheel turns are required to turn the front wheels from lock-to-lock. This steering gear ratio allows the driver to apply the least amount of turning action to obtain a large amount of front wheel turning action. While parking and cornering at low speeds, this type of steering system requires less driver hand-to-hand action on the steering wheel, which increases safety and reduces driver fatigue.

To reduce the steering ratio at low speeds, the actuator motor is driven in the same direction as the steering input, and this action over-drives the steering input. This action decreases the steering ratio, which has the effect of over-driving the steering input. This steering gear action may be compared to walking on an escalator. If you walk in the same direction as the escalator is moving, you multiply the total walking result.

As the vehicle speed increases, the ECU operates the actuator motor and planetary gear set to increase the steering ratio. At higher vehicle speeds, the steering gear ratio may be 20:1. At higher vehicle speeds, the increase in steering gear ratio dampens any sudden or excessive steering input by the driver. The increase in steering gear ratio under-drives the steering input. This action may be compared to walking against the movement of an escalator. The walking action of the person is cancelled to some extent by the escalator movement, and the person has to walk more to cover the same distance. This steering gear action reduces the possibility of the driver causing the vehicle to go into a sideways swerve (**yaw motion**) by excessive steering wheel rotation. Any excessive steering wheel rotation by the driver is immediately counteracted by an increase in steering ratio by the active steering system. This active steering system action reduces the possibility of yaw vehicle motion. Many vehicles with active steering systems are also equipped with dynamic stability control (DSC), which greatly reduces the possibility of the vehicle swerving sideways out of control. On a vehicle equipped with active steering, the DSC system will not have to operate as frequently. If an electronic defect occurs in the active steering system, the system enters a fail silent mode in which the active steering system is inoperative and the driver has normal control of the steering.

Yaw motion is an erratic deviation from an intended course such as a sideways swerve when driving a vehicle.

A Bit of History

Electronically controlled systems on vehicles have decreased emission levels, increased fuel economy, and improved driver comfort and convenience. In the near future, electronic systems on vehicles may be interconnected with intelligent transportation systems (ITS) to speed up traffic flow and reduce accidents. Some traffic experts indicate that Americans lose 2 billion working hours each year because of traffic congestion and related delays. It is estimated these traffic delays cost American employers $40 billion per year. Therefore, we can appreciate that a system to increase traffic movement could save us billions of dollars each year.

Power Steering System

The electric-drive power steering pump and the active steering system are controlled by the same ECU which contains two microprocessors. The power steering pump is a high capacity vane-cell pump that is mounted immediately in front of the steering gear (Figure 12-45). The active steering system provides faster front wheel steering angles, and this action requires a higher capacity power steering pump compared with conventional hydraulic-assisted power steering systems. The active steering ECU operates the **electronically controlled orifice (ECO) valve** in the power steering pump to control the fluid flow from the pump (Figure 12-46). The power steering pump supplies fluid pressure from the ECO valve in the pump to the **servotronic valve** in the steering gear. The active steering ECU operates the servotronic valve to increase power steering pump pressure and reduce steering effort and driver fatigue at low speeds (Figure 12-47). At higher vehicle speeds, the ECU operates the servotronic valve to reduce power steering pump pressure and increase steering effort to provide improved road feel and steering control. On some models, the active steering ECU directly operates the servotronic valve.

On other models, the software for the servotronic valve operation is stored in the active steering ECU, and this ECU sends signals through one of the CAN networks to the **safety**

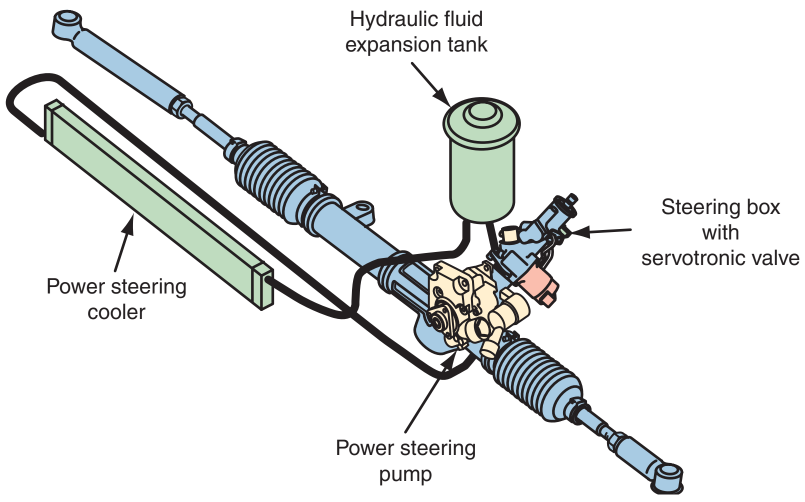


FIGURE 12-45 **Electric-drive power steering system.**

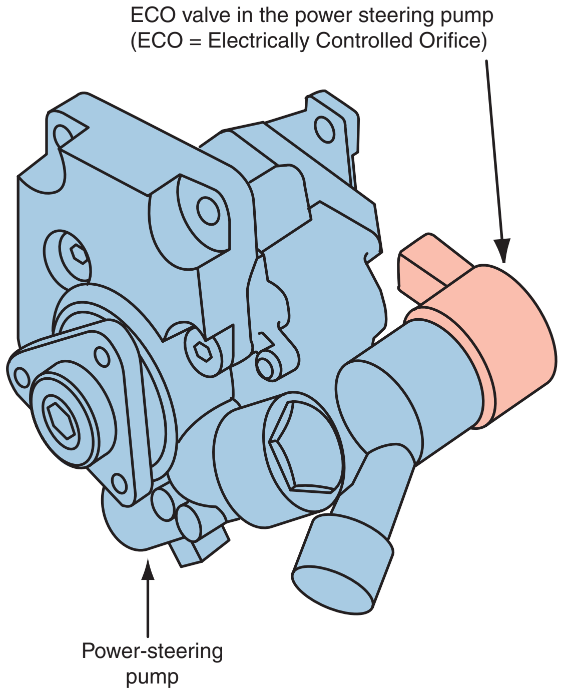


FIGURE 12-46 **Electric drive power steering pump.**

and gateway module (SGM). On the basis of these input signals, the SGM operates the servotronic valve and the ECO valve.

The input signals required for servotronic valve operation are these:

1. Road speed signals from the wheel speed sensors to the dynamic stability control (DSC) control unit via one of the CAN networks to the active steering ECU.
2. Engine status signal from the engine from the **digital motor electronics (DME)** control unit via one of the CAN networks to the active steering ECU.
3. Terminal status from the **car access system (CAS)** via one of the CAN networks to the active steering ECU.

A BIT OF HISTORY

(continued)

Oakland County, Michigan, claims to be the world's largest operational test of an ITS system. This system uses 400 video cameras at 200 intersections to transmit information to a central computer that switches traffic light operation to match traffic flow. A similar system called Faster And Safer Travel Through Traffic Routing and Advanced Controls (FAST-TRAC) is installed in Oakland County, California. The ITS or FAST-TRAC systems may contain Advanced Traveler Information Systems (ATIS). In these systems, on-board computers on vehicles receive information regarding driver information and route guidance from roadside beacons. The FAST-TRAC system in Oakland County, California, has decreased left-turn accidents by 69 percent and increased rush hour vehicle speeds by 19 percent. The U.S. Secretary of Transportation has indicated a commitment to installing ITS systems in 75 metropolitan areas in the United States with a goal of reducing travel time by 15 percent in these areas.

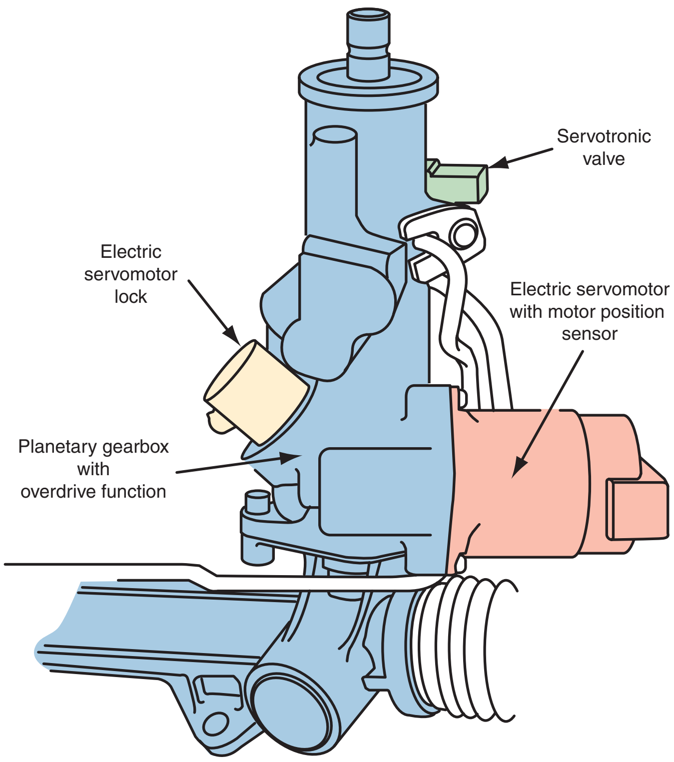


FIGURE 12-47

The servotronic valve is operated only when the engine is running. The servotronic valve enters a default mode if any of the input signals are incorrect, or if there is an electrical defect in the servotronic valve winding or connecting wires. In the default mode, the servotronic valve does not affect steering assist.

Steer-by-Wire Systems

The main difference between conventional steering systems and steer-by-wire systems is that steer-by-wire systems do not have any mechanical linkage between the steering wheel and the front wheels. In a steer-by-wire system, steering wheel input is supplied to torque sensor, gear, DC motor, and motor angle sensor (Figure 12-48). Input signals are sent to a controller

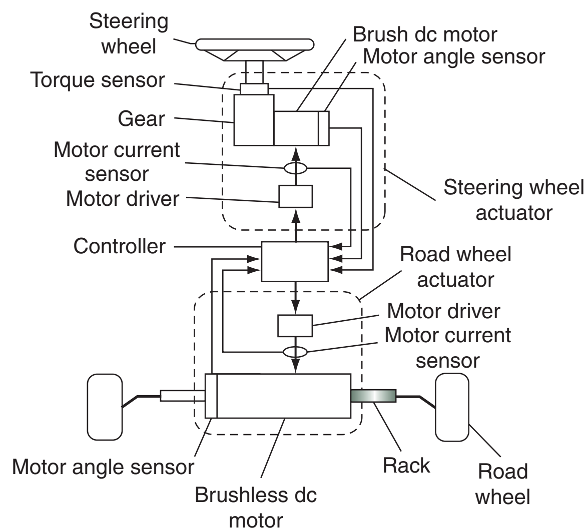


FIGURE 12-48 **Steer-by-wire system.**

from the motor angle sensor, torque sensor, and motor current sensor. On the basis of these input signals, the controller supplies output voltage signals to the motor drivers. The motor driver connected to the DC motor in the steering gear operates this motor to supply the desired steering angle.

Steer-by-wire systems are not available in automotive showrooms at present, but they may be available in the future. Steer-by-wire systems could have many possible advantages such as active steering control, improved vehicle maneuverability and stability, and steering system tuning to specific types of driving conditions. However, before steer-by-wire steering systems are commercialized, concerns regarding reliability and confirmation of advantages must be completely satisfied.

Summary

- Manual or power rack and pinion steering systems are lighter and more compact than recirculating ball steering gears and parallelogram steering linkages.
- The rack and pinion steering gear must be mounted so the rack maintains the tie-rods in a parallel position in relation to the lower control arms.
- The rack takes the place of the idler arm and pitman arm in a parallelogram steering linkage.
- The pinion teeth may be spur or helical.
- The inner tie-rods are connected to the rack through spring-loaded inner ball sockets.
- The rack bearing and adjuster plug maintains proper preload between the rack and pinion teeth.
- A rack and pinion steering gear may be mounted on the firewall or front crossmember.
- A rack and pinion steering system has fewer friction points than a recirculating ball steering gear and parallelogram steering linkage.
- Reducing the number of friction points in a steering system provides more road feel and reduces the steering system's ability to isolate road vibration and noise.
- Steering ratio is the relationship between steering wheel movement and front wheel movement to the right or left.
- During a left turn with a power rack and pinion steering gear, fluid pressure is directed to the left side of the rack piston, and fluid is released from the right side of this piston. This action moves the rack to the right to complete the left turn.
- During a right turn with a power rack and pinion steering gear, fluid pressure is directed to the right side of the rack piston, and fluid is released from the left side of this piston. Under this condition, the rack is forced to the left to help the driver complete the right turn.
- The fluid pressure in a power rack and pinion steering gear is directed to the appropriate side of the rack piston by the spool valve and rotary valve position.
- The spool valve position is controlled by torsion bar twisting during a right or left turn.
- If hydraulic pressure is not available in a power rack and pinion steering gear, stop tangs on the stub shaft and pinion provide steering action, but steering effort is much higher.

Terms to Know

Breather tube
Car access system (CAS)
Center take-off (CTO)
Column-drive EPS
Digital motor electronics (DME)
Electric locking unit (ELU)
Electronic control unit (ECU)
Electronically controlled orifice (ECO) valve
Electronic variable orifice (EVO)
Encoded disc
End take-off (ETO)
Feel of the road
Helical gear teeth
Lock-to-lock
Magnasteer system
Pinion
Pinion angle sensor
Pinion-drive EPS
Pulse width modulated (PWM) voltage signal
Rack
Rack-drive EPS
Rack piston
Rack seals
Rotary valve
Safety and gateway module (SGM)
Servotronic valve
Spool valve
Spur gear teeth
Steering angle sensor
Steering kickback
Steering ratio
Steering wheel rotation sensor

Terms to Know

(continued)

Stop-to-stop
Summation sensor
Torsion bar
Variable effort steering (VES)
Vehicle speed sensor (VSS)
Yaw motion

Summary

- The differences between Saginaw and TRW power rack and pinion steering gears are mainly in the method of tie-rod attachment, bulkhead oil seal and retainer, and upper and lower pinion bearing hardware.
- The Toyota power rack and pinion steering gear has a removable control valve housing and claw washers to lock the inner tie-rods to the rack.
- The electronic variable orifice (EVO) steering system provides high power steering assistance during low-speed cornering and parking and normal power assistance at higher speeds.
- The two inputs in the EVO system are the steering wheel rotation sensor and the vehicle speed sensor.

Review Questions

Short Answer Essays

1. Explain why the rack and pinion steering gear is ideally suited for unibody front-wheel-drive vehicles.
2. Identify the component in a parallelogram steering linkage that compares to the rack in a rack and pinion steering gear.
3. Describe the difference between spur and helical gear teeth, and explain the advantage of helical gear teeth.
4. Explain the purpose of the bellows boots in a rack and pinion steering gear.
5. Describe two possible mounting positions for rack and pinion steering gears.
6. Explain why a rack and pinion steering gear provides improved feel of the road compared with a recirculating ball steering gear and parallelogram steering linkage.
7. Describe the fluid movement in the rack piston chamber during a right turn.
8. Explain how the spool valve is moved inside the rotary valve in a power rack and pinion steering gear.
9. Explain the operation of each input sensor in a Ford electronic variable orifice (EVO) steering system.
10. Describe the driving conditions required for an electronic variable orifice (EVO) steering system to provide high-power steering assistance.

Fill-in-the-Blanks

1. The preload on the rack and pinion teeth affects steering harshness, noise, and _______________.
2. Compared to a recirculating ball steering gear and parallelogram steering linkage, a rack and pinion steering system has a reduced ability to isolate road noise and vibration because the rack and pinion system has fewer_______________ _______________.
3. During a left turn, the power steering pump forces fluid into the _______________ side of the rack chamber, and fluid is removed from the _______________ side of this chamber.
4. During a turn, fluid is directed to the appropriate side of the rack piston chamber by the _______________ valve and _______________ valve position.
5. When the torsion bar twists, it changes the position of the _______________ valve.
6. In an end take-off power rack and pinion steering gear, the tie-rods are connected to the _______________.
7. In a center take-off power rack and pinion steering gear, the tie-rods are attached to a _______________ _______________.
8. In an EVO steering system, the power steering assistance is decreased at higher speeds to provide improved _______________ _______________.
9. The input sensors in an EVO steering system are the vehicle speed sensor and the _______________ _______________ _______________ _______________.
10. In an EVO steering system, the actuator solenoid is mounted in the _______________ _______________ _______________.

Multiple Choice

1. Compared to a recirculating ball steering gear, a rack and pinion steering gear provides:
   A. Improved capability to isolate road noise.
   B. Better capability to reduce steering harshness on road irregularities.
   C. Increased capability to absorb steering kickback.
   D. Increased road feel.

2. If the lock-to-lock steering wheel rotation is 4 turns and the total front wheel movement is 75 degrees, the steering ratio is:
   A. 15.6:1.
   B. 16.1:1.
   C. 18.4:1.
   D. 19.2:1.

3. All of these statements about a power rack and pinion steering gear are true EXCEPT:
   A. During a left turn fluid pressure is directed to the left side of the rack piston.
   B. During a right turn fluid pressure is directed to the right side of the rack piston.
   C. Fluid is directed to the appropriate side of the rack piston by the position of the rotary valve inside the spool valve.
   D. The spool valve is moved by torsion bar twisting during a turn.

4. In an active steering system:
   A. The steering shaft is connected to the pinion gear.
   B. The electric motor drives the planetary ring gear through a wormdrive.
   C. The ELU locks the planetary gear set if a defect occurs.
   D. The active steering system may have a 20:1 steering ratio during low-speed cornering.

5. In a power rack and pinion steering gear the breather tube:
   A. Vents the right rack piston chamber during a left turn.
   B. Moves air from one boot to the other during a turn.
   C. Allows air into the rotary valve area while driving straight ahead.
   D. Prevents pressure buildup in both rack piston chambers when driving straight ahead.

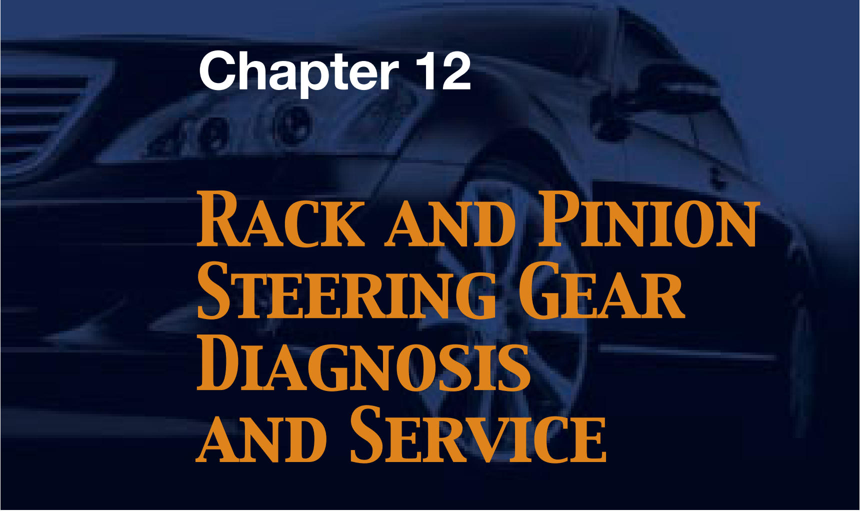
6. The power steering pump belt breaks on a rack and pinion power steering system. Under this condition:
   A. The torsion bar may be broken when the front wheels are turned to the right or left.
   B. The steering operates like a manual steering system, and steering effort is higher.
   C. The spool valve no longer moves inside the rotary valve when the steering wheel is turned.
   D. Power steering fluid may be forced from the rack seals when the steering wheel is turned.

7. In electronic variable orifice (EVO) steering systems:
   A. Steering assistance is increased if vehicle speed is above 25 mph (40 km/h).
   B. The control unit operates a relay in the steering gear to control steering assist.
   C. Steering assistance is increased if the vehicle speed is below 10 mph (16 km/h) and steering wheel rotation is above 15 rpm.
   D. The control unit increases steering assistance at higher speed to provide improved road feel.

8. All of these statements about electronic power steering are true EXCEPT:
   A. The system remains operational if the engine stalls and the ignition switch is on.
   B. The power module is a separate unit from the electronic power steering control unit.
   C. The power module controls current flow through the steering gear motor with a pulse width modulated (PWM) voltage signal.
   D. The interface in the steering sensor rectifies AC current to DC current and amplifies the steering sensor voltage signals.

9. If an electrical defect occurs in the electronic power steering (EPS) system:
   A. The system continues to operate normally, but the EPS warning light is illuminated.
   B. The system continues to operate with a slightly reduced power steering assist.
   C. The EPS control unit shuts the system down by opening the fail safe and power relays.
   D. The EPS control unit locks the armature in the steering gear to prevent armature and screw shaft damage.

10. In an electronic power steering (EPS) system:
    A. The EPS control unit determines the direction of steering wheel rotation from the steering sensor signals.
    B. The variable differential transformer in the steering sensor contains one primary and one secondary winding.
    C. When driving straight ahead, the slider in the steering sensor is at the lower end of its travel.
    D. The vehicle speed sensor (VSS) voltage signal is sent directly to the EPS control unit.



Chapter 12

Rack and Pinion Steering Gear Diagnosis and Service

Upon completion and review of this chapter, you should be able to:

- Perform a manual or power rack and pinion steering gear inspection.
- Remove and replace manual or power rack and pinion steering gears.
- Disassemble, inspect, repair, and reassemble manual rack and pinion steering gears.
- Adjust manual rack and pinion steering gears.
- Diagnose manual rack and pinion steering systems.
- Diagnose oil leaks in power rack and pinion steering gears.
- Disassemble, inspect, and repair power rack and pinion steering gears.
- Adjust power rack and pinion steering gears.
- Diagnose Magnasteer.
- Diagnose electronic power steering systems.

Proper rack and pinion steering gear operation is essential to maintain vehicle safety and reduce driver fatigue. Such steering gear conditions as looseness and excessive steering effort may contribute to a loss of steering control, resulting in a vehicle collision. Worn steering gear mountings may cause improper wheel alignment and **bump steer**. Improper wheel alignment increases tire tread wear, and bump steer may increase driver fatigue. Excessive steering gear looseness or high steering effort also contribute to driver fatigue. Therefore, in the interest of vehicle safety and driver alertness, rack and pinion steering gear diagnosis and service are extremely important.

BASIC TOOLS

Basic technician's tool set

Service manual

Floor jack

Safety stands

Machinist's rule

Manual or Power Rack and Pinion Steering Gear On-Car Inspection

The wear points are reduced to four in a rack and pinion steering gear. These wear points are the inner and outer tie-rod ends on both sides of the rack and pinion assembly (Figure 12-1).

The first step in manual or power rack and pinion steering gear diagnosis is a very thorough inspection of the complete steering system. During this inspection, all steering system components such as the inner and outer tie-rod ends, **bellows boots,** mounting bushings, couplings or universal joints, ball joints, tires, and **steering wheel free play** must be checked.

Bump steer occurs when one of the front wheels strikes a road irregularity while driving straight ahead, and the steering suddenly veers to the right or left.

Follow these steps for manual or power rack and pinion steering gear inspection:

1. With the front wheels straight ahead and the engine stopped, rock the steering wheel gently back and forth with light finger pressure (Figure 12-2). Measure the maximum steering wheel free play. The maximum specified steering wheel free play on some vehicles is 1.18 in. (30 mm). Always refer to the vehicle manufacturer's specifications in the service manual. Excessive steering wheel free play indicates worn steering components.

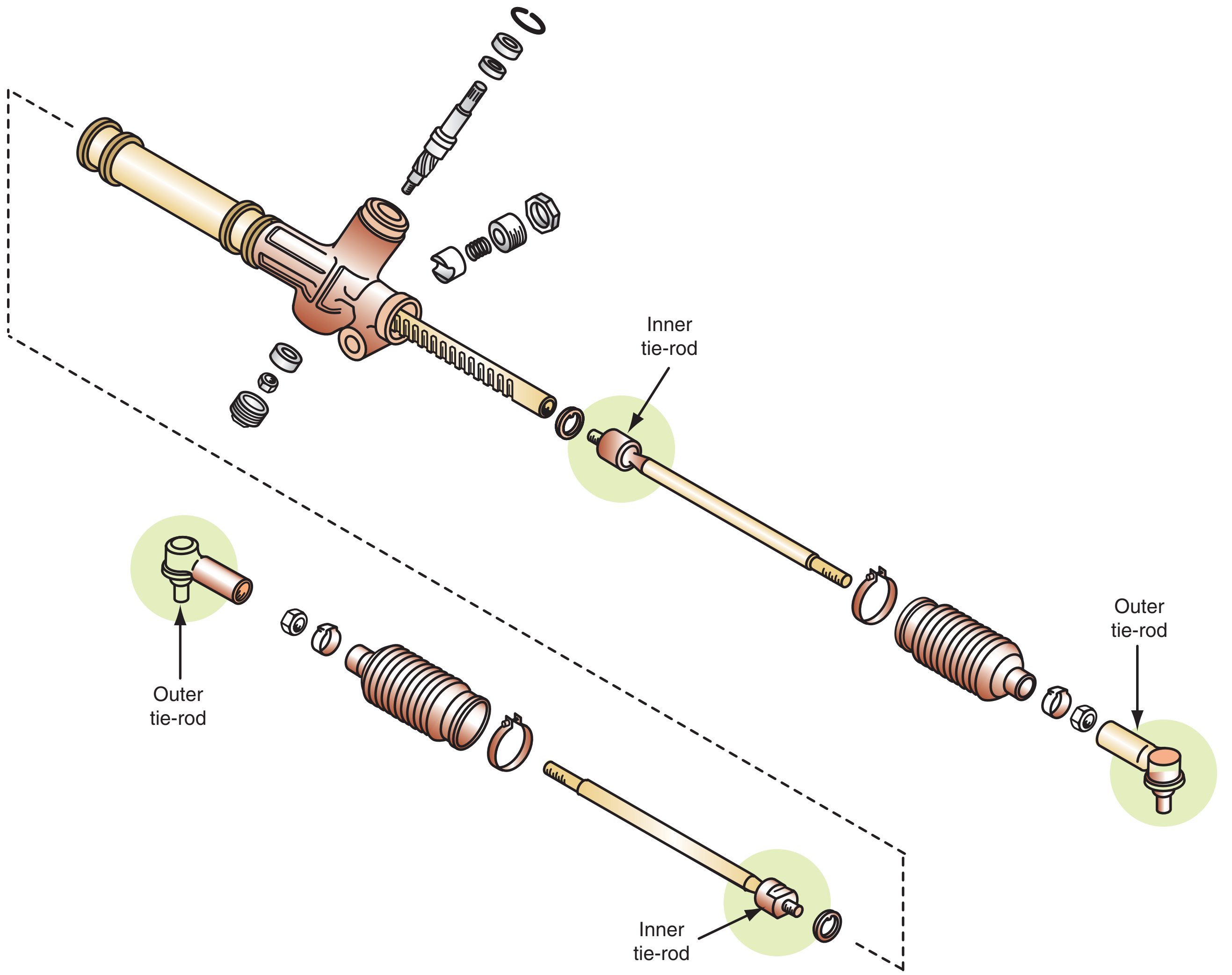


FIGURE 12-1 **Wear points at the inner and outer tie-rod ends in a rack and pinion steering gear.**

Bellows boots are clamped over each end of the steering gear housing to keep dirt out of the rack.

Steering wheel free play is the distance that the steering wheel moves before the front wheels begin to turn when the steering wheel is rocked back and forth with light finger pressure.

FIGURE 12-2 **Checking steering wheel free play.**

2. With the vehicle sitting on the shop floor and the front wheels straight ahead, have an assistant turn the steering wheel about 1/4 turn in both directions. Watch for looseness in the flexible coupling or universal joints in the steering shaft. If looseness is observed, replace the coupling or universal joint.
3. While an assistant turns the steering wheel about 1/2 turn in both directions, watch for movement of the steering gear housing in the mounting bushings. If there is any movement of the housing in these bushings, replace the bushings. The steering gear mounting bushings may be deteriorated by oil soaking, heat, or age.
4. Grasp the pinion shaft extending from the steering gear and attempt to move it vertically. If there is steering shaft vertical movement, a pinion bearing preload adjustment may be required. When the steering gear does not have a pinion bearing preload adjustment, replace the necessary steering gear components.
5. Road test the vehicle and check for excessive steering effort. A bent steering rack, tight rack bearing adjustment, or damaged front drive axle joints in a front-wheel-drive car may cause excessive steering effort.
6. Visually inspect the bellows boots for cracks, splits, leaks, and proper clamp installation. Replace any boot that indicates any of these conditions. If the boot clamps are loose or improperly installed, tighten or replace the clamps as necessary. Since the bellows boots protect the inner tie-rod ends and the rack from contamination, boot condition is extremely important. Boots should be inspected each time under-car service such as oil and filter change or chassis lubrication is performed.
7. Loosen the inner bellows boot clamps and move each boot toward the outer tie-rod end until the inner tie-rod end is visible. Push outward and inward on each front tire, and watch for movement in the inner tie-rod end. If any movement or looseness is present, replace the inner tie-rod end. An alternate method of checking the inner tie-rod ends is to squeeze the bellows boots and grasp the inner tie-rod end socket. Movement in the inner tie-rod end is then felt as the front wheel is moved inward and outward. Hard plastic bellows boots may be found on some applications. With this type of bellows boot, remove the ignition key from the switch to lock the steering column and push inward and outward on the front tire while observing any lateral movement in the tie-rod. When lateral movement is observed, replace the inner tie-rod end.

WARNING: Bent steering components must be replaced. Never straighten steering components, because this action may weaken the metal and result in sudden component failure, serious personal injury, and vehicle damage.

8. Grasp each outer tie-rod end and check for vertical movement. While an assistant turns the steering wheel 1/4 turn in each direction, watch for looseness in the outer tie-rod ends. If any looseness or vertical movement is present, replace the tie-rod end. Check the outer tie-rod end seals for cracks and proper installation of the nuts and cotter pins. Cracked seals must be replaced. Inspect the tie-rods for a bent condition. Bent tie-rods or other steering components must be replaced. Do not attempt to straighten these components.

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Manual or Power Rack and Pinion Steering Gear Removal and Replacement

The replacement procedure is similar for manual or power rack and pinion steering gears. This removal and replacement procedure varies depending on the vehicle. On some vehicles, the front crossmember or engine support cradle must be lowered to remove the rack and pinion steering gear. Always follow the vehicle manufacturer's recommended procedure in the service manual.

The following is a typical rack and pinion steering gear removal and replacement procedure:

1. Place the front wheels in the straight-ahead position and remove the ignition key from the ignition switch to lock the steering wheel. Place the driver's seat belt through the steering wheel to prevent wheel rotation if the ignition switch is turned on (Figure 12-3). This action maintains the clock spring electrical connector or spiral cable in the centered position on air-bag-equipped vehicles.
2. Lift the front end with a floor jack, and place safety stands under the vehicle chassis. Lower the vehicle onto the safety stands. Remove the left and right fender apron seals (Figure 12-4).

FIGURE 12-3 **Driver's seat belt wrapped around the steering wheel to prevent wheel rotation.**

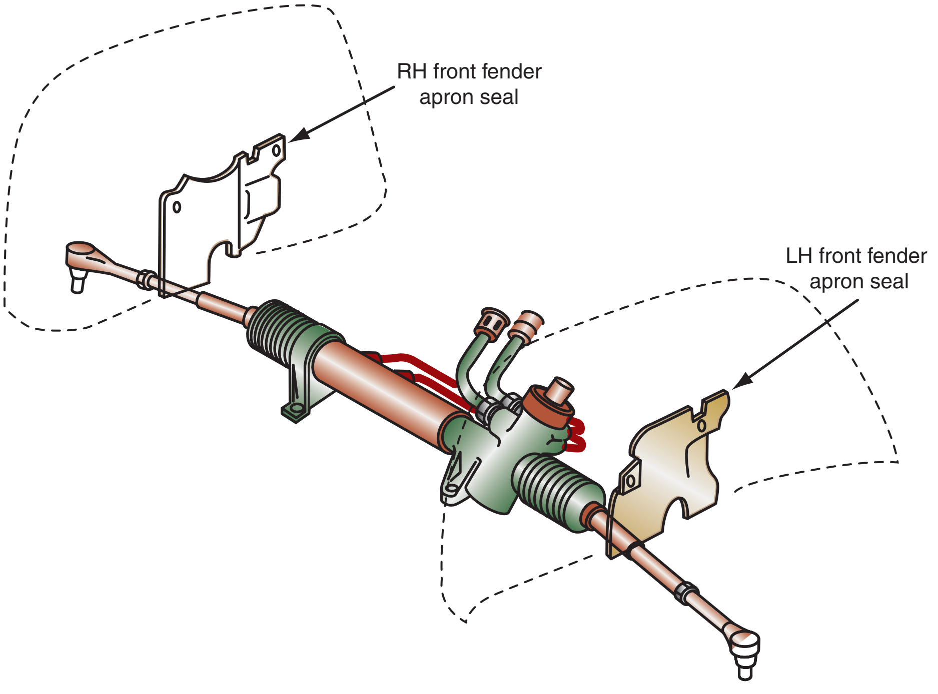


FIGURE 12-4 **Left and right fender apron seals.**

3. Place punch marks on the lower universal joint and the steering gear pinion shaft so they may be reassembled in the same position (Figure 12-5). Loosen the upper universal joint bolt, remove the lower universal joint bolt, and disconnect this joint.
4. Remove the cotter pins from the outer tie-rod ends. Loosen, but do not remove, the tie-rod end nuts. Use a tie-rod end puller to loosen the outer tie-rod ends in the steering arms (Figure 12-6). Remove the tie-rod end nuts and remove the tie-rod ends from the arms.
5. Use the proper wrenches to disconnect the high-pressure hose and the return hose from the steering gear (Figure 12-7). This step is not required on a manual steering gear. The removal procedure for a power rack and pinion steering gear is shown in Photo Sequence 21.
6. Remove the four stabilizer bar mounting bolts (Figure 12-8).
7. Remove the steering gear mounting bolts (Figure 12-9).
8. Remove the steering gear assembly from the right side of the car (Figure 12-10).
9. Position the right and left tie-rods the specified distance from the steering gear housing (Figure 12-11). Install the steering gear through the right fender apron.
10. Install the pinion shaft in the universal joint with the punch marks aligned. Tighten the upper and lower universal joint bolts to the specified torque.
11. Install the steering gear mounting bolts and tighten these bolts to the specified torque.

SPECIAL TOOLS
Tie-rod end puller

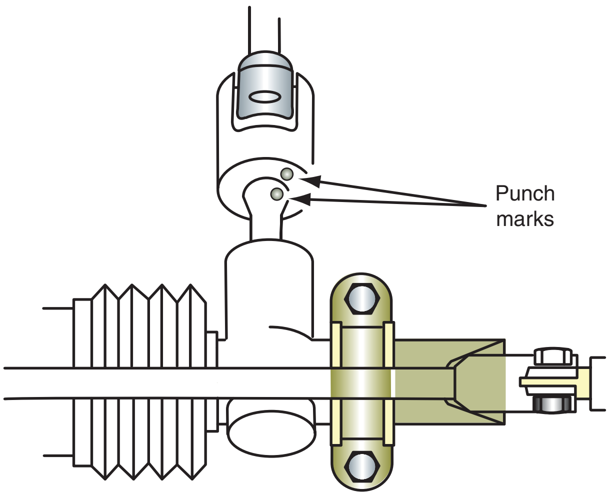


FIGURE 12-5 **Punch marks on universal joint and pinion shaft.**

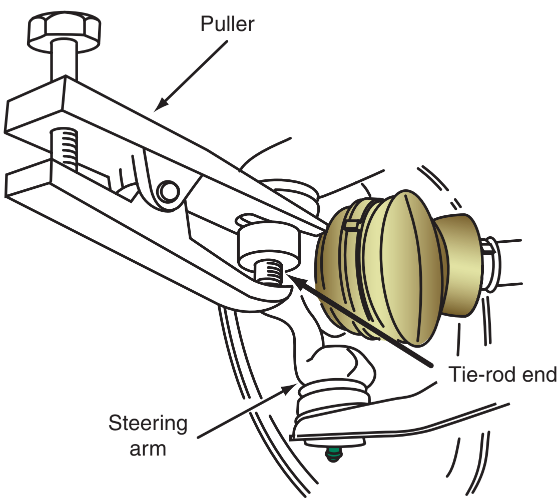


FIGURE 12-6 **Removing outer tie-rod ends.**

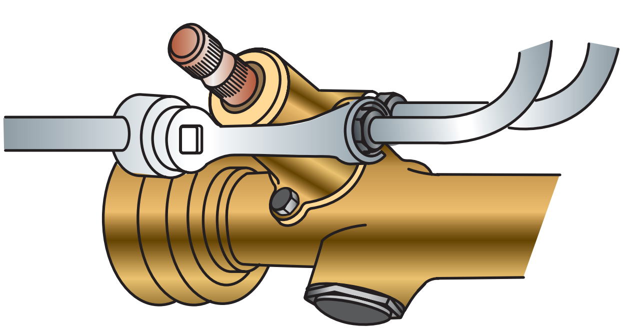


FIGURE 12-7 **Removing high-pressure and return hoses from steering gear.**

FIGURE 12-8 **Removing stabilizer bar mounting bolts.**

FIGURE 12-9 **Removing steering gear mounting bolts.**

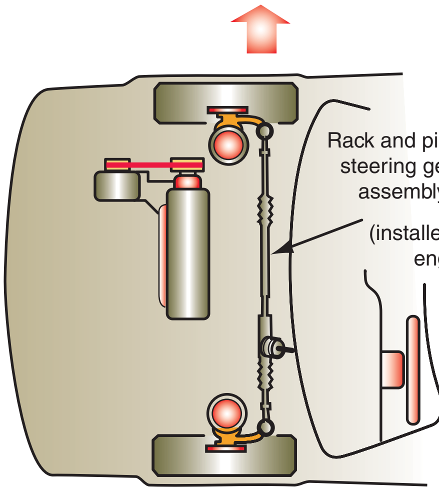


FIGURE 12-10 **Removing steering gear from the car.**

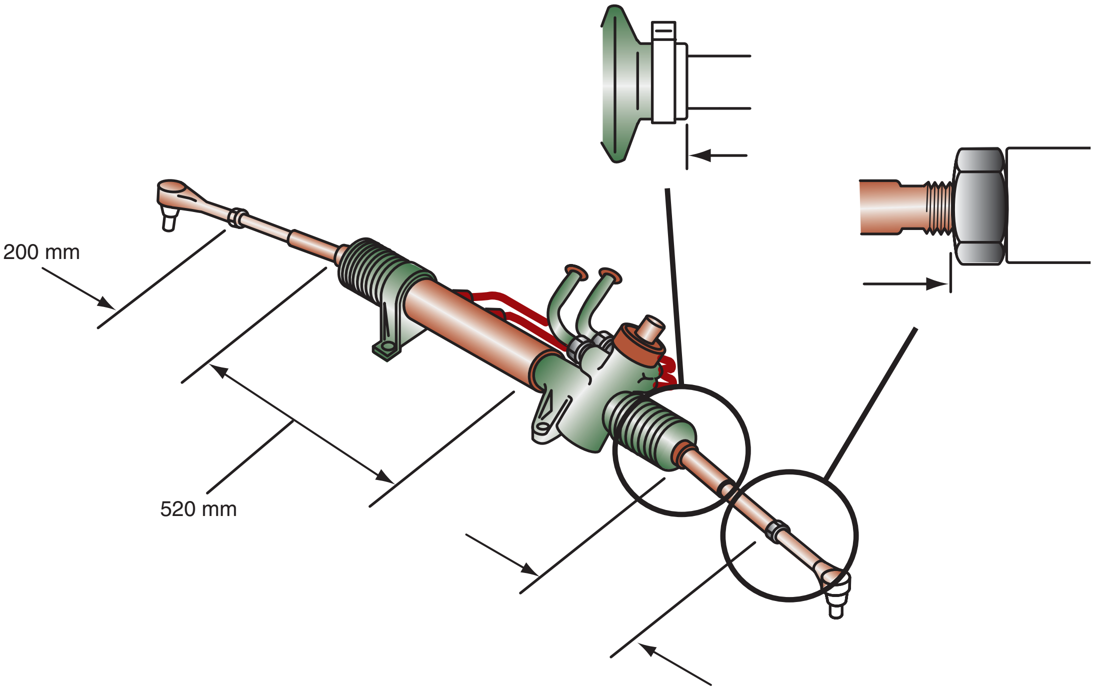


FIGURE 12-11 **Right and left tie-rod position in relation to the steering gear housing prior to installation.**

CAUTION:
Do not loosen the tie-rod end nuts to align cotter pin holes. This action causes improper torquing of these nuts.

12. Install the stabilizer bar mounting bolts and torque these bolts to specifications.
13. Install and tighten the high-pressure and return hoses to the specified torque. (This step is not required on a manual rack and pinion steering gear.)
14. Install the outer tie-rod ends in the steering knuckles, and tighten the nuts to the specified torque. Install the cotter pins in the nuts.
15. Check the front wheel toe and adjust as necessary. Tighten the outer tie-rod end jam nuts to the specified torque, and tighten the outer bellows boot clamps.
16. Install the left and right fender apron seals, and lower the vehicle with a floor jack.
17. Fill the power steering pump reservoir with the vehicle manufacturer's recommended power steering fluid and bleed the air from the power steering system. (Refer to Chapter 10 for these tasks. This step is not required on a manual rack and pinion steering gear.)
18. Road test the vehicle and check for proper steering gear operation and steering control.

Typical Procedure for Removing and Replacing a Power Rack and Pinion Steering Gear

P21-1 **Position the vehicle on a tire-contact lift, and place the front wheels in the straight-ahead position.**

P21-2 **Remove the key from the ignition switch to lock the steering column, and place the driver's seat belt through the steering wheel opening to prevent wheel rotation if the ignition switch is turned on.**

P21-3 **Raise the vehicle a short distance off the floor, and remove the left and right fender apron seals.**

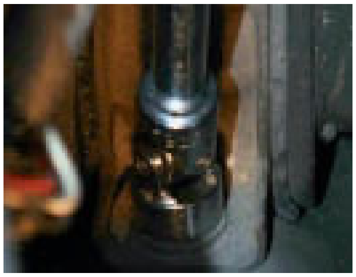
P21-4 **Place punch or chalk marks on the lower universal joint and steering gear pinion shaft so they may be reassembled in the same position.**

P21-5 **Loosen the upper universal joint bolt, remove the lower universal joint bolt, and disconnect the lower universal joint.**

P21-6 **Remove the cotter pins from the outer tie-rod ends, and loosen but do not remove the tie-rod end nuts. Use a tie-rod end puller to loosen the outer tie-rod ends in the steering arms. Remove the tie-rod end nuts, and remove the tie-rod ends from the steering arms.**

P21-7 **Use the proper size wrenches to remove the high-pressure hose and return hose from the steering gear.**

P21-8 **Remove the four stabilizer bar mounting bolts.**

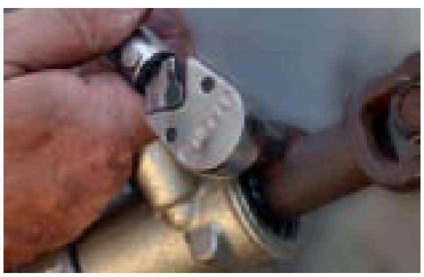


P21-9 **Remove the steering gear mounting bolts.**

P21-10 Remove the steering gear through one of the fender apron openings.

P21-11 Measure the distance from the outer end of the steering gear housing to the outer edge of the outer tie-rod end on both sides of the steering gear, and record these measurements.

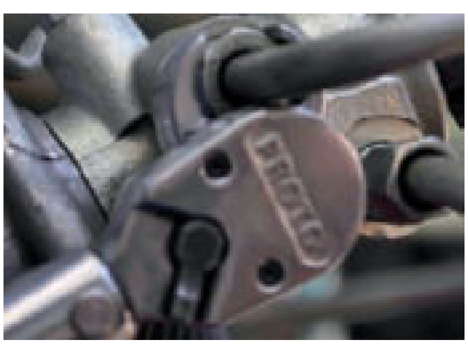
P21-12 Rotate the pinion shaft to obtain the measurements obtained in step 11, and install the steering gear through one of the fender apron openings.



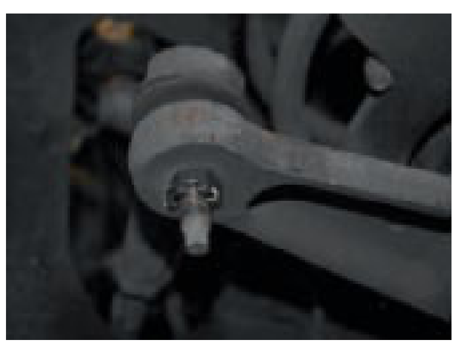
P21-13 Install the pinion shaft into the universal joint with the punch marks aligned. Tighten the upper and lower universal joint bolts to the specified torque.

P21-14 Install the steering gear mounting bolts and tighten these bolts to the specified torque.

P21-15 Install the stabilizer mounting bolts and tighten these bolts to the specified torque.



P21-16 Install and tighten the high-pressure and return line fittings to the specified torque.



P21-17 Install the outer tie-rod ends in the steering arms, and tighten the retaining nuts to the specified torque. Install the cotter pins in the nuts.

P21-18 Lower the vehicle to a convenient working height, and install the fender apron seals.

P21-19 **Fill the power steering pump reservoir to the proper level with the specified power steering fluid. Start the engine for a short time, then shut the engine off, and add power steering fluid as required. Run the engine for several minutes, turn the steering wheel fully in both directions, and then add power steering fluid as necessary.**

Manual Rack and Pinion Steering Gear Diagnosis and Service

Manual Rack and Pinion Steering Gear Tie-Rod Service

Follow these steps for manual rack and pinion steering gear disassembly:

1. Clamp the center of the steering gear housing in a **soft-jaw vise.** Do not apply excessive force to the vise.
2. Insert a short piece of wire through each outer tie-rod end cotter pin hole and connect a pull scale to this wire. Pull upward on the scale to check the tie-rod articulation effort (Figure 12-12). If this effort is not within specifications, replace the inner tie-rod end.
3. Mark the outer tie-rod and jam nut position with masking tape wrapped around the tie-rod threads next to the jam nut, or place a dab of paint on the jam nut and tie-rod threads (Figure 12-13). Loosen the jam nuts and remove the outer tie-rod ends.

A **soft-jaw vise** has brass jaws to prevent marking components.

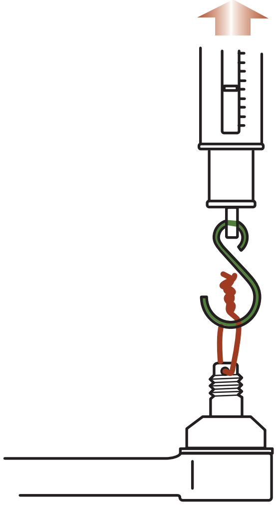


FIGURE 12-12 **Measuring inner tie-rod end articulation effort.**

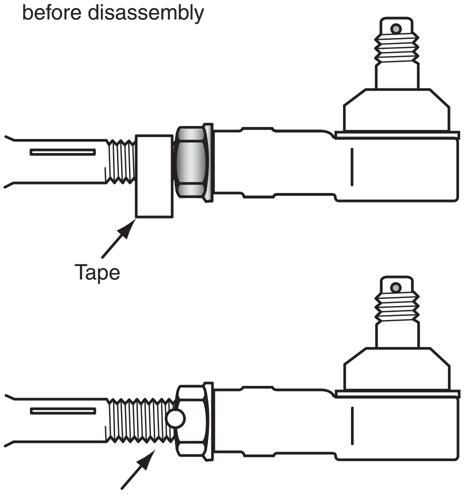


FIGURE 12-13 **Marking outer tie-rod end and jam nut position.**

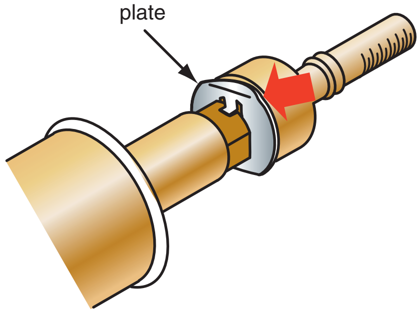


FIGURE 12-14 **Straightening lock plate where it is bent over the inner tie-rod end.**

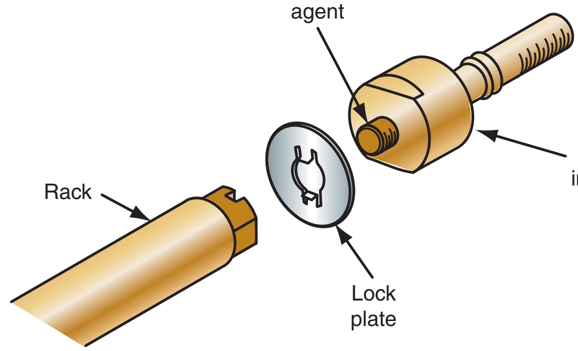


FIGURE 12-15 **Removing inner tie-rod end from the rack.**

4. Remove the inner and outer bellows boot clamps and pull the bellows boots from the tie-rods.
5. Hold the rack in a soft-jaw vise and straighten the lock plate where it is bent over the inner tie-rod end (Figure 12-14). Hold the rack with a wrench, and use the proper size wrench to remove the inner tie-rod end from the rack (Figure 12-15). A jam nut is used in place of the lock ring on some inner tie-rod ends, and a roll pin retains some inner tie-rod ends to the rack. Various inner tie-rod socket removal procedures are required depending on the socket design.
6. Rotate the inner tie-rod ends onto the rack until they bottom. Install the inner tie-rod pins, or stake these ends as required. Always use a wooden block to support the opposite side of the rack and inner tie-rod end while staking. If jam nuts are located on the inner tie-rod ends, be sure they are tightened to the specified torque.
7. Place a large bellows boot clamp over each end of the gear housing. Install the bellows boots, and be sure the boots are seated in the housing and the tie-rod undercuts. Install and tighten the large inner boot clamps.
8. Install the outer bellows boot clamps on the tie-rods, but do not install these clamps on the boots until the steering gear is installed and the toe is adjusted.
9. Install the jam nuts and the outer tie-rod ends. Align the marks placed on these components during the disassembly procedure. Leave the jam nuts loose until the steering gear is installed and the toe is adjusted.
10. Install the steering gear in the vehicle and check the front wheel toe. Tighten the outer bellows boot clamps and the outer tie-rod end jam nuts.

Diagnosis of Manual Steering and Suspension Systems

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It is sometimes difficult to separate the diagnosis of manual steering gears, steering columns, and suspension systems because some noises and symptoms may be caused by problems in any of these components or systems. Diagnostic information on three common steering problems is provided in Table 12-1. Refer to the vehicle manufacturer's service manual for complete diagnosis.

Power Rack and Pinion Steering Gear Diagnosis and Service

Fluid, Filter, and Fluid Leak Diagnosis

Power steering fluid should be inspected for discoloration and contamination with metal particles, dirt, or water. A suction gun may be used to remove some fluid from the power steering reservoir for inspection. If the fluid is contaminated or discolored, the power steering system

TABLE 12-1 **DIAGNOSIS OF MANUAL STEERING GEARS, SUSPENSION SYSTEMS, AND STEERING COLUMNS**

Condition	Possible Cause	Correction
Loose steering	1. Steering linkage connections loose	1. Tighten as required.
	2. Steering linkage ball stud rubber deteriorated	2. Replace as required.
	3. Pitman arm-to-steering-gear attaching nut loose	3. Tighten to specifications.
	4. Flex coupling-to-steering-gear attaching bolt loose	4. Tighten the bolt to specifications.
	5. Intermediate shaft-to-steering-column-shaft attaching bolt loose	5. Tighten the bolt to specifications.
	6. Flex coupling damaged or worn	6. Replace as required.
	7. Front and/or rear suspension components loose, damaged, or worn	7. Tighten or replace as required.
	8. Steering gear adjustment set too low	8. Check the steering gear adjustment and readjust as required.
Noise: Knock, clunk, rapping, squeaking noise when turning	1. Steering wheel-to-steering-column shroud interference	1. Adjust or replace as required.
	2. Lack of lubrication where speed control brush contacts steering wheel pad	2. Lubricate as required.
	3. Steering column mounting bolts loose	3. Tighten the bolt to specifications.
	4. Intermediate shaft-to-steering-column-shaft attaching bolt loose	4. Tighten the bolt to specifications.
	5. Flex coupling-to-steering-gear attaching bolt loose	5. Tighten the bolt to specifications.
	6. Steering gear mounting bolts loose	6. Tighten the bolt to specifications.
	7. Tires rubbing or grounding out against body or chassis	7. Adjust/replace as required.
	8. Front suspension components loose, worn, or damaged	8. Tighten or replace as required.
	9. Steering linkage ball stud rubber deteriorated	9. Replace as required.
	10. Normal lash between sector gear teeth and ball nut gear teeth when the steering gear is in the off-center position permits gear tooth chuckle noise while turning on rough road surfaces	10. This is a normal condition and cannot be eliminated.
Vehicle pulls/drifts to one side *Note:* This condition cannot be caused by the manual steering gear.	1. Vehicle overloaded or unevenly loaded	1. Correct as required.
	2. Improper tire pressure	2. Adjust air pressure as required.
	3. Mismatched tires and wheels	3. Install correct tire and wheel combination.
	4. Unevenly worn tires	4. Replace as required (check for cause).
	5. Loose, worn, or damaged steering linkage	5. Tighten or replace as required.
	6. Steering linkage stud not centered within the socket	6. Repair or replace as required.
	7. Bent spindle or spindle arm	7. Repair or replace as required.
	8. Broken and/or sagging front and/or rear suspension springs	8. Replace as required.
	9. Loose, bent, or damaged suspension components	9. Tighten or replace as required.
	10. Bent rear axle housing	10. Replace as required.
	11. Excessive camber/caster split (excessive side-to-side variance in the caster/camber settings)	11. Adjust camber/caster split as required.
	12. Improper toe setting	12. Adjust as required.
	13. Front wheel bearings out of adjustment	13. Adjust as required.
	14. Investigate tire variance (conicity for radial tires and unequal circumference for bias-ply and belted bias-ply tires)	14. Repair or replace as required.

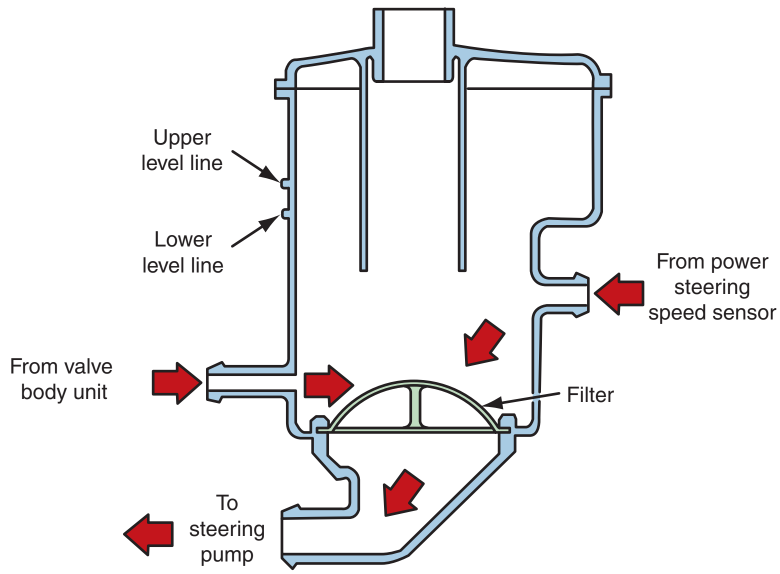


FIGURE 12-16 **Power steering reservoir and filter.**

must be flushed and then filled to the specified level with the vehicle manufacturer's specified fluid. After refilling the power steering system, an air bleeding procedure is usually necessary. Some power steering systems have a filter that is usually located in the remote power steering reservoir (Figure 12-16). On some systems, the filter and reservoir must be replaced as an assembly. Filter/reservoir replacement is necessary if the power steering system has been opened for repairs or if the fluid is contaminated with water, metal, or dirt particles. The filter/reservoir and fluid should also be changed at the vehicle manufacturer's specified service intervals. A restricted power steering filter may cause erratic steering operation.

WARNING: If the engine has been running for a length of time, power steering gears, pumps, lines, and fluid may be very hot. Wear eye protection and protective gloves when servicing these components.

If power steering fluid leaks from the cylinder end of the power steering gear, the outer rack seal is leaking (Figure 12-17).

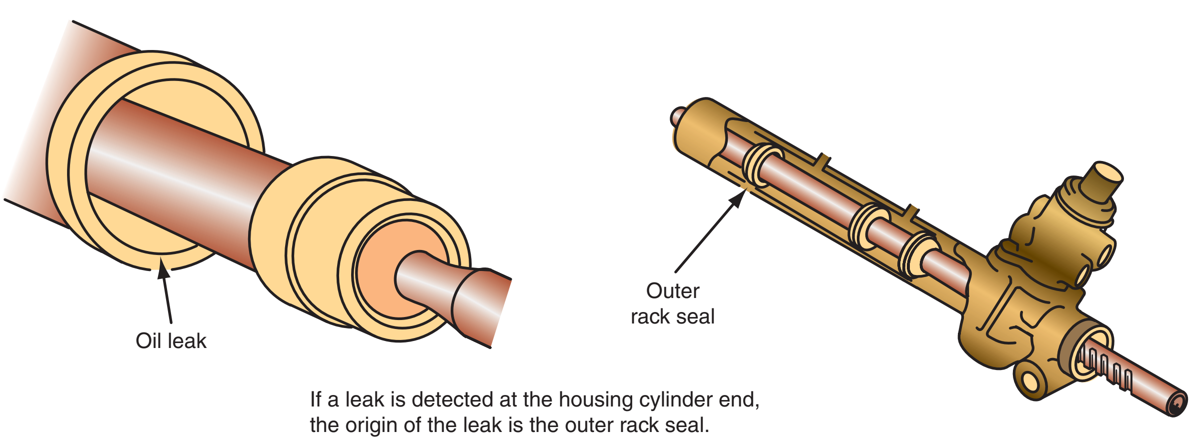
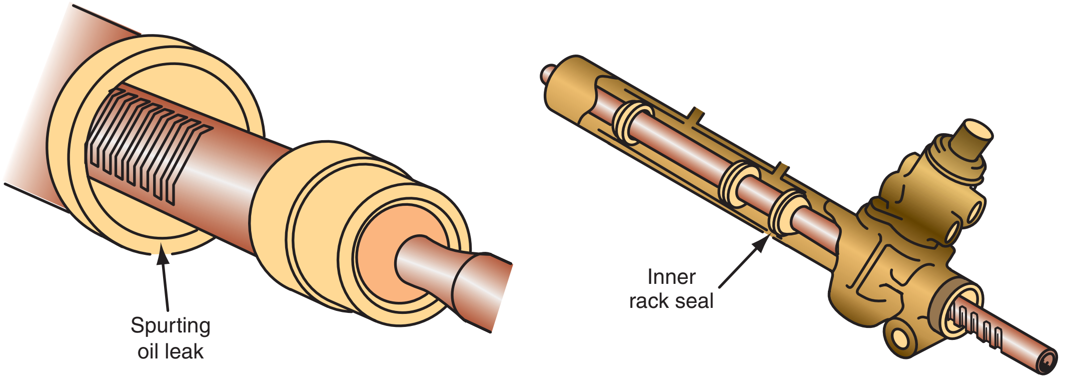


FIGURE 12-17 **Oil leak diagnosis at outer rack seal.**

The inner rack seal is defective if oil leaks from the pinion end of the housing when the rack reaches the left internal stop (Figure 12-18). An oil leak at one rack seal may result in oil leaks from both boots because the oil may travel through the breather tube between the boots.

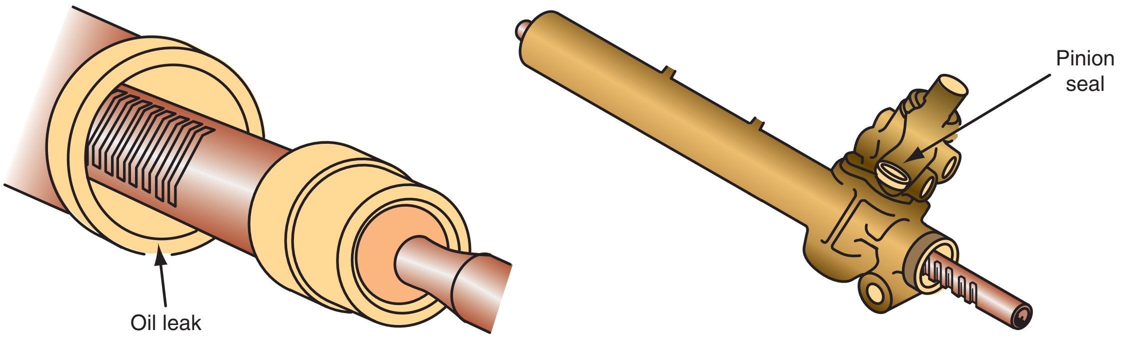
If an oil leak occurs at the pinion end of the housing and this leak is not influenced when the steering wheel is turned, the pinion seal is defective (Figure 12-19).

If an oil leak occurs in the pinion coupling area, the input shaft seal is leaking (Figure 12-20). This seal and the pinion seal will require replacement because the pinion seal must be replaced if the pinion is removed.



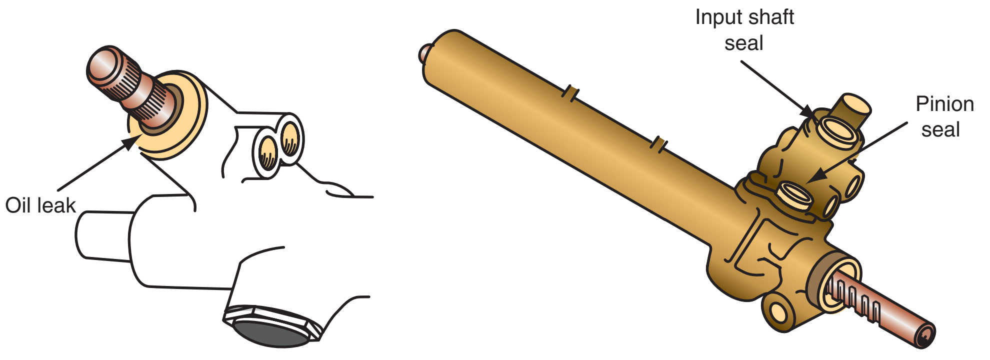
If the leak at the pinion end of the housing spurts when the rack reaches the left internal stop, the inner rack seal is at fault.

FIGURE 12-18 **Inner rack seal leak diagnosis.**



If you detect a leak at the pinion end of the housing and it is not influenced by the direction of the turn, the origin of the leak is the pinion seal.

FIGURE 12-19 **Pinion seal leak diagnosis.**



If you discover a leak at the pinion coupling area, you'll have to replace both the input shaft seal and the lower pinion seal.

FIGURE 12-20 **Oil leak diagnosis on pinion coupling area.**

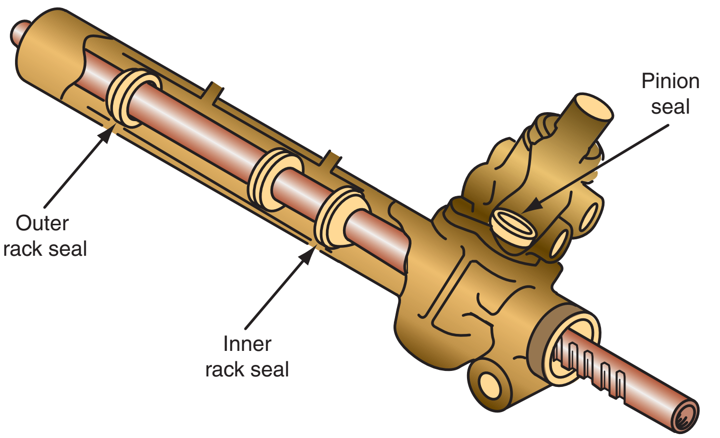


FIGURE 12-21 **Rack seals and pinion seal.**

SERVICE TIP: To provide equal turning effort in both directions, the rack must be centered with the front wheels straight ahead.

When the rack is removed, the inner and outer rack seals and the pinion seal must be replaced (Figure 12-21). If oil leaks occur at fittings, these fittings must be torqued to the manufacturer's specifications. If the leak is still present, the line and fitting should be replaced. Leaks in the lines or hoses require line or hose replacement.

Turning Imbalance Diagnosis

Steering effort imbalance is the difference in steering effort when making right and left turns.

The same amount of effort should be required to turn the steering wheel in either direction. A pressure gauge connected to the high-pressure hose should indicate the same pressure when the steering wheel is turned in each direction. **Steering effort imbalance** or lower power assist in each direction may be caused by defective rack seals (Figure 12-22). Steering

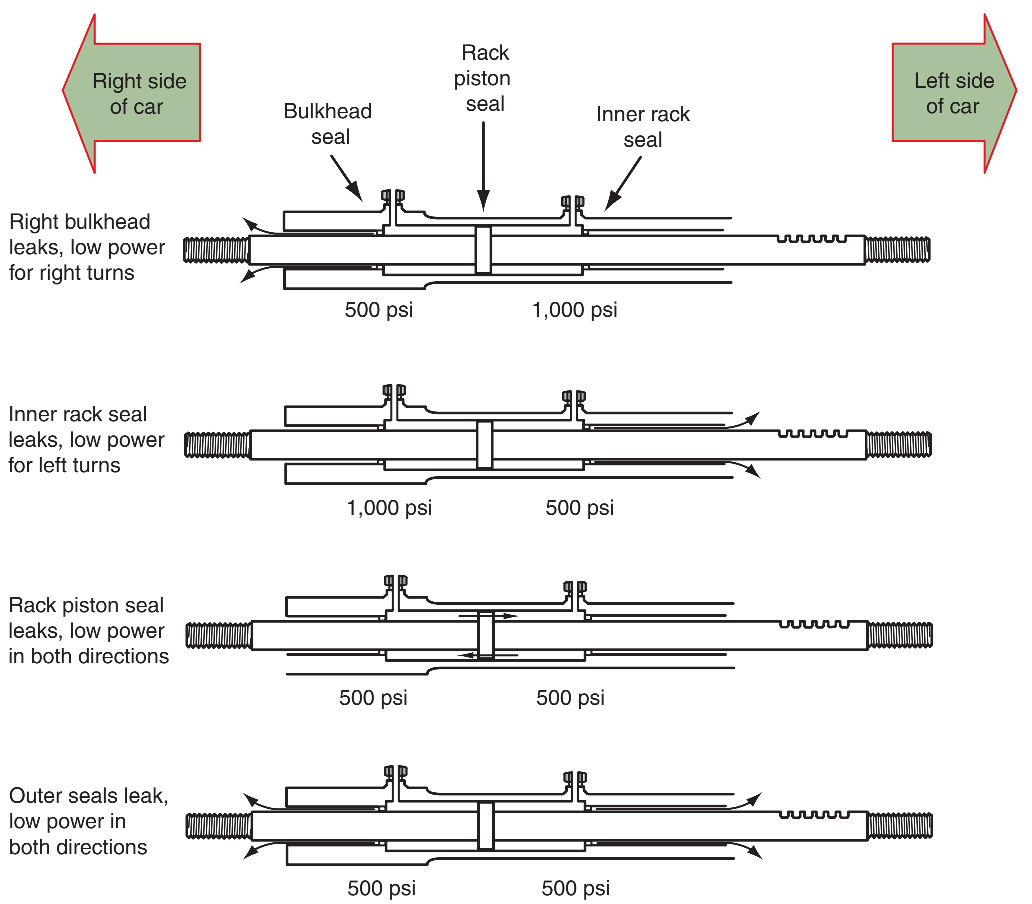


FIGURE 12-22 **Effect of defective rack seals on steering effort imbalance and low power assist.**

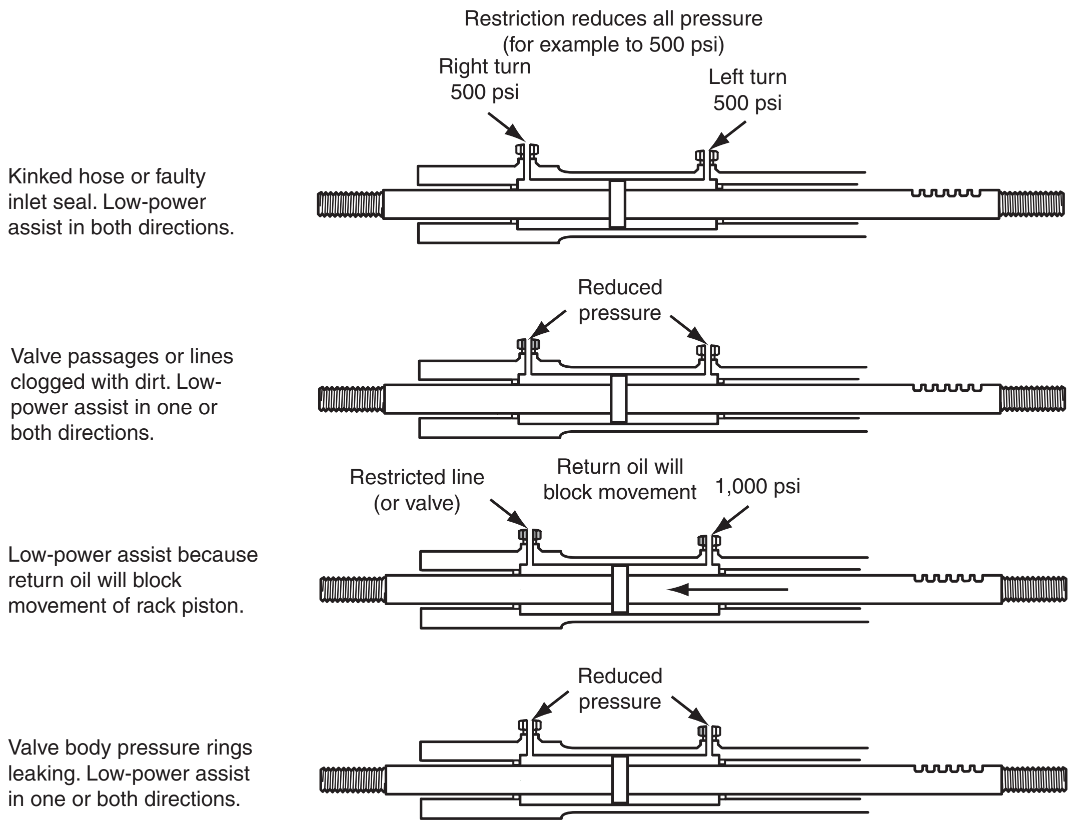


FIGURE 12-23 **Effect of worn rotary valve rings and seals or restricted lines or hoses on steering effort.**

effort imbalance or low power assist in both directions may also be caused by defective rotary valve rings and seals or restricted hoses and lines (Figure 12-23).

Power Rack and Pinion Steering Gear Tie-Rod and Rack Bearing Service

1. Install a holding tool on the steering gear housing, and clamp this tool in a vise (Figure 12-24).
2. Mark the outer tie-rod ends, jam nuts, and tie-rods (Figure 12-25). Loosen the jam nuts and remove the tie-rod ends and jam nuts.
3. Loosen the inner and outer clamps on both bellows boots, and remove these boots (Figure 12-26).
4. Clamp the inner tie-rod socket lightly in a soft-jaw vise and use a hammer and chisel to unstake the **claw washers** on the inner tie-rod sockets (Figure 12-27).

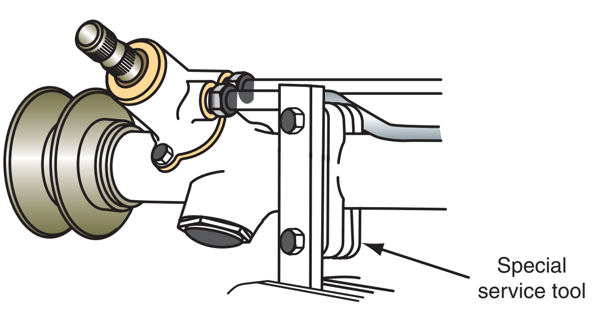


FIGURE 12-24 **Steering gear holding tool.**

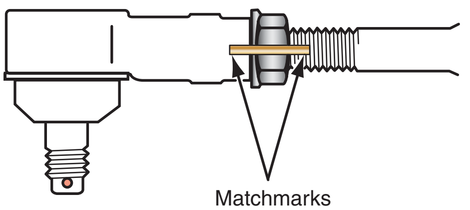


FIGURE 12-25 **Marking outer tie-rod ends, jam nuts, and tie-rods prior to outer tie-rod end removal.**

In a power rack and pinion steering gear, a condition that causes excessive steering effort when the vehicle is first started may be called "morning sickness."

SPECIAL TOOLS

Steering gear holding tool

Claw washers are used in some steering gears to lock the tie-rods to the rack.

SERVICE TIP:

A common problem with power rack and pinion steering gears is excessive steering effort when the car is first started after sitting overnight. The steering effort becomes normal, however, after the steering wheel is turned several times. This problem usually indicates severe scoring where the pinion sealing rings contact the pinion housing. Steering gear replacement is required to correct this problem.

FIGURE 12-26 **Removing bellows boot clamps.**

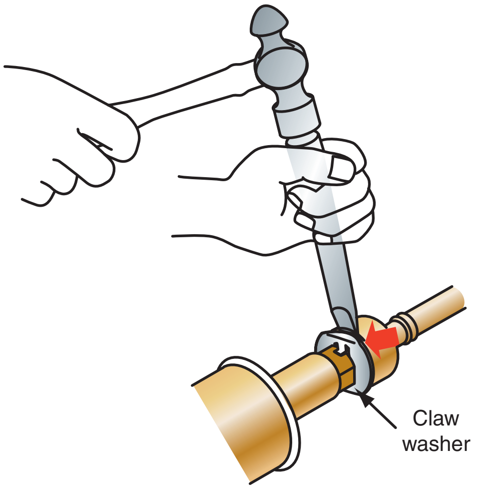


FIGURE 12-27 **Removing claw washers from inner tie-rod sockets.**

SERVICE TIP:
In some power rack and pinion steering gears, the inner tie-rod ends are staked after they are installed on the rack (refer to Photo Sequence 22 later in this chapter). In other power rack and pinion steering gears, a pin retains the inner tie-rod ends to the rack, and this pin must be removed before the inner tie-rod ends are removed. When the inner tie-rod ends are replaced, a new retaining pin must be installed.

5. Hold the rack with an adjustable wrench and use the proper tool to loosen the inner tie-rod ends (Figure 12-28). Remove the inner tie-rod ends and the claw washers.
6. Use the proper tool to loosen the adjuster plug locknut (Figure 12-29).
7. Remove the adjuster plug with the proper tool (Figure 12-30).
8. Remove the spring, rack guide, and the seat from the adjuster plug opening(Figure 12-31).

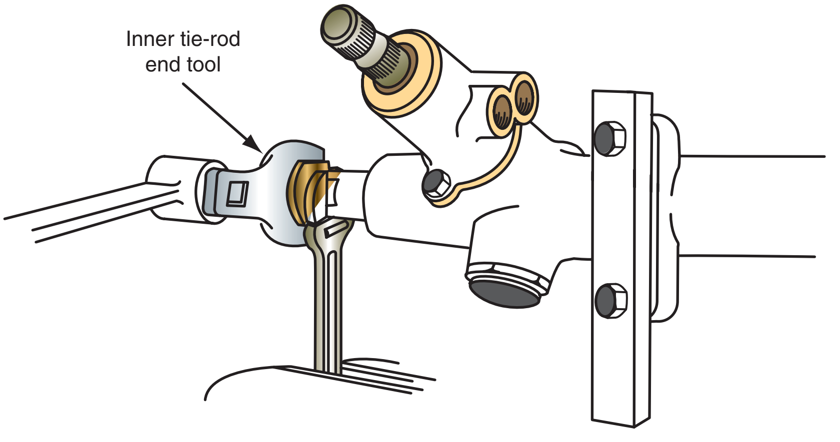


FIGURE 12-28 **Loosening inner tie-rod ends.**

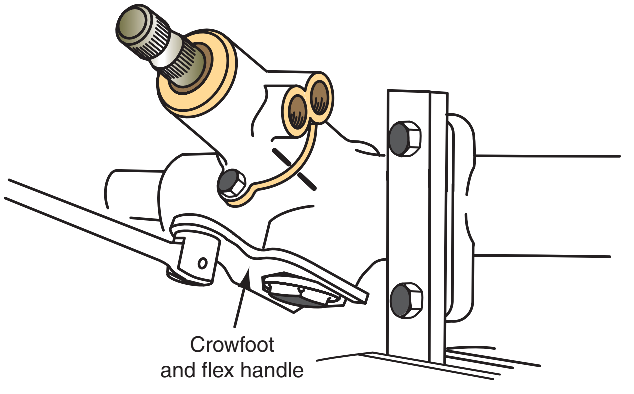


FIGURE 12-29 **Loosening adjuster plug locknut.**

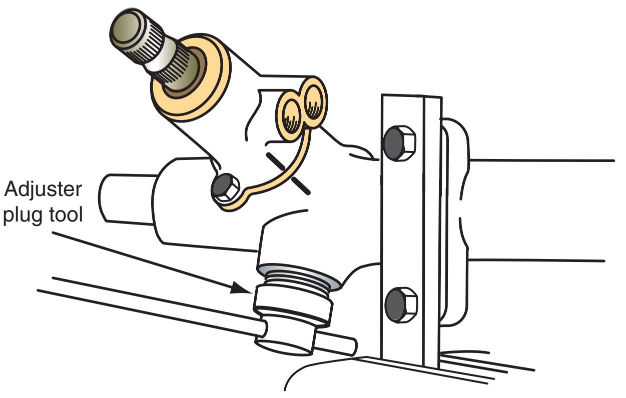


FIGURE 12-30 **Removing adjuster plug.**

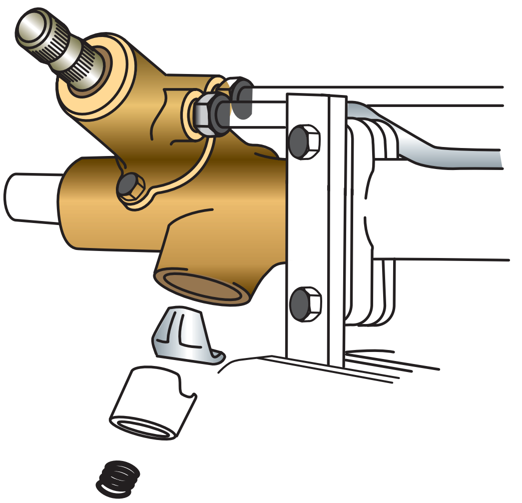


FIGURE 12-31 **Removing spring, rack guide, and seat.**

9. Clean and inspect the spring, rack guide, and seat. Replace only worn components. Lubricate the rack guide and seat with the specified power steering fluid.
10. Coat the rack guide seat and rack guide with power steering fluid. Install the rack guide seat, rack guide, and spring (Figure 12-32). Apply Loctite 242 sealant or its equivalent to the first two or three threads on the rack spring cap. Install the rack spring cap and tighten it to the specified torque (Figure 12-33).
11. Use the proper tool to rotate the rack spring cap 12° counterclockwise. Turn the pinion shaft fully in each direction, and repeat this action. Loosen the rack spring cap until there is no tension on the rack guide spring. Place the proper turning tool and a foot-pound torque wrench on top of the pinion shaft. Tighten the rack spring cap while rotating the pinion shaft back and forth (Figure 12-34). Continue tightening the rack spring cap until the specified turning torque is indicated on the torque wrench.

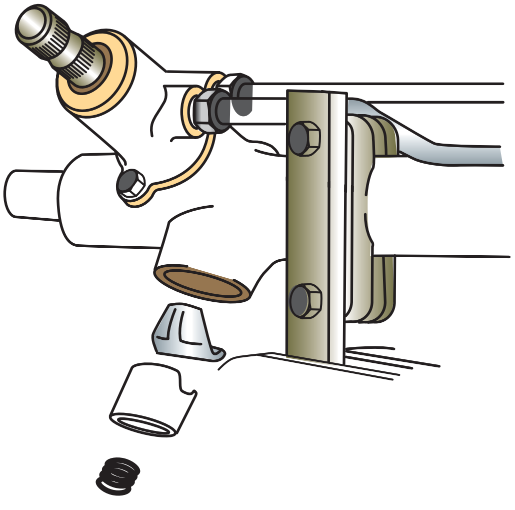


FIGURE 12-32 **Installing rack guide seat, rack guide, and spring.**

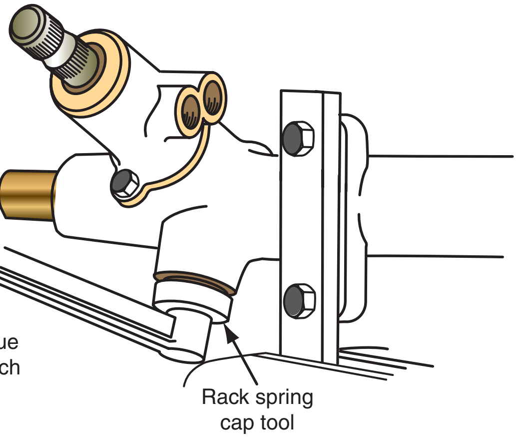


FIGURE 12-33 **Installing rack spring cap.**

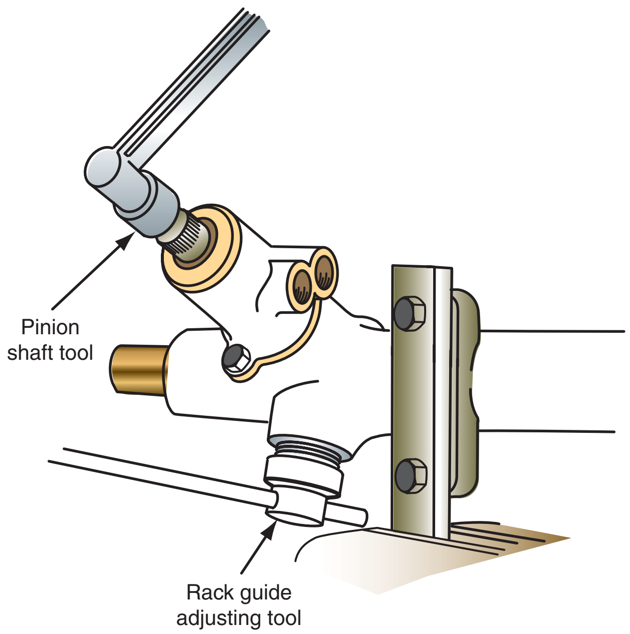


FIGURE 12-34 **Adjusting pinion shaft turning torque.**

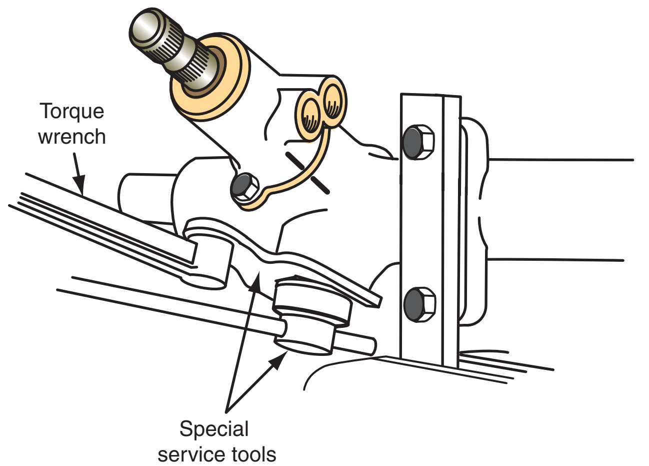


FIGURE 12-35 **Tightening locknut on rack spring cap.**

12. Apply Loctite 242 sealant or its equivalent to the first two or three threads on the locknut. Install the locknut on the rack spring cap. Use the proper tool to hold the rack spring cap, and tighten the locknut to the specified torque (Figure 12-35).
13. Install a new claw washer on the inner tie-rod end, and then install the inner tie-rod end on the rack. Hold the rack with an adjustable wrench, and use a torque wrench with the correct tool to tighten the inner tie-rod end to the specified torque (Figure 12-36). Clamp the inner tie-rod end in a soft-jaw vise and stake the claw washer with a brass bar and a hammer (Figure 12-37). Repeat this procedure on both inner tie-rod ends.

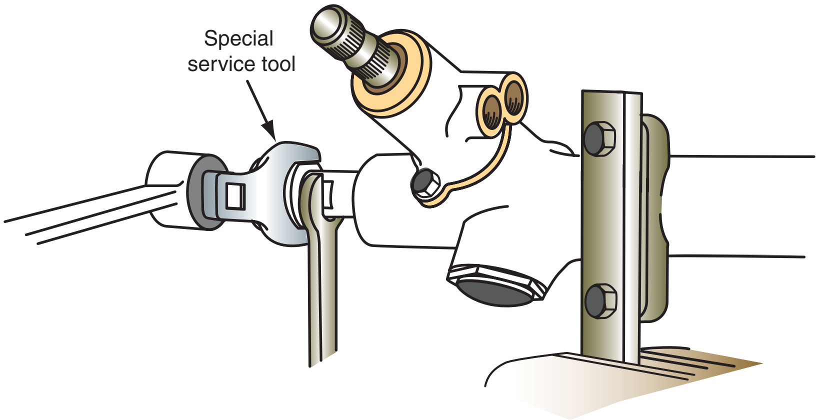


FIGURE 12-36 **Tightening inner tie-rod end on the rack.**

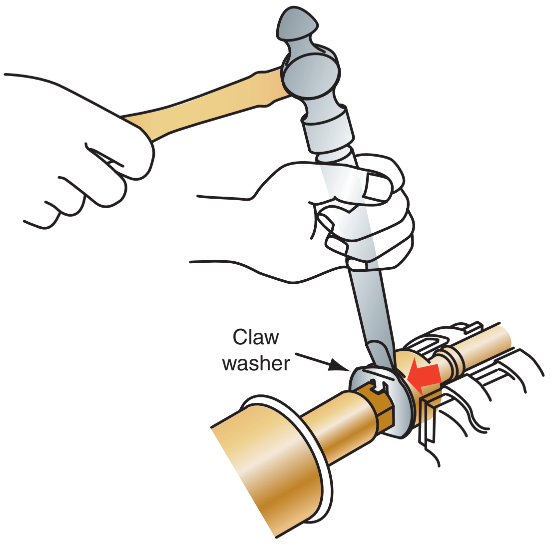


FIGURE 12-37 **Staking claw washer on inner tie-rod end.**

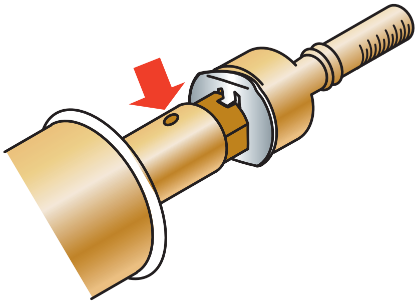


FIGURE 12-38 **Rack vent holes must be open.**

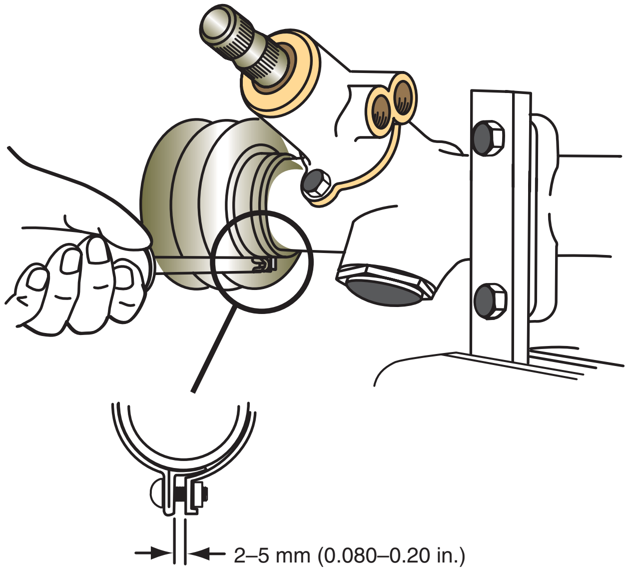


FIGURE 12-39 **Minimum clearance between boot clamp ends.**

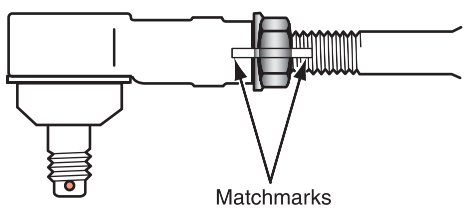


FIGURE 12-40 **Aligning marks on the outer tie-rod ends, jam nuts, and tie-rods.**

14. Check the vent hole in each end of the rack and be sure they are not clogged with grease or other material (Figure 12-38). These vent holes allow air flow from one boot to the other during a turn.
15. Install the bellows boots, clamps, and clips. When the inner boot clamps are tightened, there must be a minimum of 2 mm (0.08 in.) between the ends of the clamps (Figure 12-39).
16. Install the outer tie-rod ends and jam nuts. Align the marks placed on the tie-rod ends, jam nuts, and tie-rods during disassembly (Figure 12-40). Leave the jam nuts loose until the steering gear is installed and the front wheel toe is adjusted.
17. Follow the steering gear installation procedure described earlier in this chapter to install the steering gear in the vehicle. Tighten all fasteners to the specified torque. (See Chapter 10 for power steering pump filling and bleeding procedure.) Check the front wheel toe and tighten the outer tie-rod end jam nuts to the specified torque. Tighten the outer bellows boot clamps. Road test the vehicle and check for proper steering operation and control.

Photo Sequence 22 shows a typical procedure for removing and replacing an inner tie-rod end on a power rack and pinion steering gear.

PHOTO SEQUENCE 22

Typical Procedure for Removing and Replacing Inner Tie-Rod End, Power Rack, and Pinion Steering Gear

P22-1 **Place an index mark on the outer tie-rod end, jam nut, and tie-rod.**

P22-2 **Loosen the jam nut and remove the outer tie-rod end and jam nut.**

P22-3 **Remove the inner and outer boot clamps.**

P22-4 **Remove the bellows boot from the tie-rod.**

P22-5 **Hold the rack with the proper size wrench and loosen the inner tie-rod end with the proper wrench.**

P22-6 **Remove the inner tie-rod from the rack.**

P22-7 **Be sure the shock damper ring is in place on the rack.**

P22-8 **Install the inner tie-rod on the rack, and tighten the tie-rod to the specified torque while holding the rack with the proper size wrench.**

P22-9 **Support the inner tie-rod on a vise, and stake both sides of the inner tie-rod joint with a hammer and punch.**

P22-10 **Use a feeler gauge to measure the clearance between the rack and the inner tie-rod joint housing stake.**

P22-11 **Install the bellows boot and new clamps.**

P22-12 **Install the jam nut and outer tie-rod end with the index marks aligned.**

DIAGNOSIS OF POWER STEERING, STEERING COLUMN, AND SUSPENSION SYSTEMS

Some power steering problems may be caused by defects in the steering gear, pump, or column. For example, heavy steering effort may be caused by a defective power steering pump, damaged rack piston and ring, or misalignment of the steering column. Diagnostic information on common power steering problems is provided in Table 12-2. Refer to the vehicle manufacturer's service manual for more complete diagnosis.

SERVICE TIP:
A scored cylinder surface in the steering gear housing may cause temporary excessive steering effort after the car sits overnight.

TABLE 12-2 **POWER STEERING SYSTEM, STEERING COLUMN, AND SUSPENSION SYSTEM DIAGNOSIS**

Condition	Possible Cause	Correction
Wander: The vehicle wanders side to side on the roadway when it is driven straight ahead, while the steering wheel is held in a firm position. Evaluation should be conducted on a level road (little road crown).	1. Loose/worn tie-rod ends or ball socket	1. Replace tie-rod end or tie-rod assembly.
	2. Inner ball housing loose or worn	2. Replace tie-rod assemblies.
	3. Gear assembly loose crossmember	3. Tighten the two mounting nuts to specification.
	4. Excessive yoke clearance	4. Adjust yoke clearance.
	5. Loose suspension struts or ball joints	5. Tighten or replace as required.
	6. Column intermediate shaft connecting bolts loose	6. Tighten bolts to specification at gear and column.
	7. Column intermediate shaft joints loose or worn	7. Replace intermediate shaft assembly.
	8. Improper wheel alignment	8. Set alignment to specification.
	9. Tire size and pressure	9. Check tire sizes and adjust tire pressure.
	10. Vehicle unevenly loaded or overloaded	10. Adjust load.
	11. Steering gear mounting insulators and/or attachment bolts loose or damaged	11. Replace insulators and/or attachment nuts and bolts. Tighten to specification.
	12. Steering gear adjustments	12. Refer to steering gear section of *Shop Manual.*
	13. Front end misaligned	13. Check and align to specifications.
	14. Worn front end parts or wheel bearings	14. Inspect and replace affected parts.
	15. Unbalanced or badly worn steering gear control valve	15. Inspect and replace affected parts.

(Continued)

TABLE 12-2 (continued)

Condition	Possible Cause	Correction
Pulls to one side: The vehicle tends to pull to one side when driven on a level surface.	1. Improper tire pressure	1. Adjust tire pressure.
	2. Improper tire size or different type	2. Replace as required.
	3. Vehicle unevenly or excessively loaded	3. Adjust load.
	4. Improper wheel alignment	4. Adjust as required.
	5. Damaged front suspension components	5. Refer to front suspension section of Shop Manual.
	6. Damaged rear suspension components	6. Refer to rear suspension section of Shop Manual.
	7. Steering gear valve effort out of balance	7. Place transmission in Neutral while driving and turn engine off (coasting). — If vehicle does not pull, replace the steering gear valve assembly. Refer to steering gear section of Shop Manual. — If vehicle does drift: • Cross-switch front tire/wheel assemblies. • If vehicle pulls to opposite side, cross-switch tire/wheel assemblies that were on the rear to the same on the front. • If vehicle pull direction is not changed, check front suspension components and wheel alignment.
	8. Front and rear brakes operation	8. Adjust if necessary.
	9. Bent rear axle housing, or damaged or sagging springs in the front and/or rear suspension	9. Replace if necessary.
	10. Loose/worn shock absorber or suspension attaching fasteners in rear suspension	10. Tighten all attaching fasteners to specification.

CAUTION:
Always be sure the ignition switch is off when connecting or disconnecting the scan tool. Computer system and/or scan tool damage may occur if the ignition switch is on when connecting or disconnecting the scan tool from the data link connector (DLC).

Diagnosis of Magnasteer Systems

The most common customer complaints on Magnasteer systems are continually heavy or light steering effort. When diagnosing a Magnasteer system, the first step is to visually inspect the system. Be sure the power steering fluid level is correct, and check the power steering belt tension. Inspect the wiring harness connected to the actuator solenoid in the steering gear.

If the visual inspection does not locate any defects, connect a scan tool to the DLC near the steering column under the dash (Figure 12-41). Turn the ignition switch on and select the Electronic Brake and Traction Control Module (EBTCM) on the scan tool menu. If there is an electrical defect in the actuator solenoid, connecting wires, or EBTCM, Diagnostic Trouble Code (DTC) C1241 will be displayed on the scan tool. To locate the exact cause of this DTC, perform voltmeter tests on the actuator solenoid and connecting wires. A detailed diagnostic chart is included in the vehicle manufacturer's service manual.

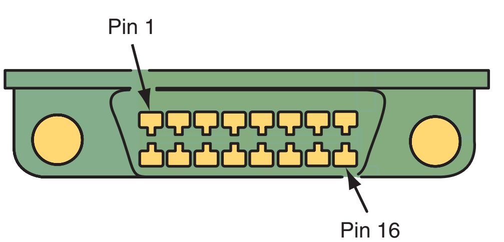


FIGURE 12-41 **Data link connector (DLC) on-board diagnostic II (OBD-II) system.**

If the customer complains about continually heavy or light steering and there are no defects in the Magnasteer system, reprogramming of the system may be required.

To reprogram the system, follow these steps:

1. Connect the scan tool to the DLC.
2. Select Magnasteer and Recalibration on the scan tool.
3. Respond to the VIN query on the scan tool. If the displayed VIN is incorrect, enter the correct VIN.
4. When Factory Standard Calibration Will Be Used For This VIN appears on the scan tool, press Enter on the scan tool to install factory calibration.
5. When calibration is complete, disconnect the scan tool.

SERVICE TIP:
Some generic scan tools do not have the capability to reprogram computers.

Diagnosis of Rack-Drive Electronic Power Steering

When the ignition switch is turned on, in a vehicle with **rack-drive electronic power steering** electronic power steering (EPS) light in the instrument panel should be illuminated (Figure 12-42). This EPS light action proves the bulb and related circuit are functioning normally. When the engine starts, the EPS light is turned off by the EPS control unit if there are no electrical defects in the EPS system. The EPS light should remain off while the engine is running.

If an electrical defect occurs in the EPS system, the EPS control unit turns on the EPS light to alert the driver that a defect exists in the EPS system. Under this condition, the EPS control unit shuts down the EPS system, and electric assist is no longer available. Manual steering with increased steering effort is provided in this mode. When the EPS control unit senses an electrical defect in the EPS system, a diagnostic trouble code (DTC) is stored in the control unit memory. The EPS control unit memory is erased if battery voltage is disconnected from the control unit. The 7.5 ampere clock fuse may be disconnected for 10 seconds to disconnect battery voltage from the EPS control unit and erase the DTCs from the control unit memory.

If the EPS light is on with the engine running, shut the ignition switch off and disconnect the clock fuse for 10 seconds; then road test the car to determine if the EPS light comes back on. If the EPS light comes on again with the engine running, proceed with the diagnosis. Locate the two-wire EPS service check connector under the glove box. With the ignition switch off, connect a special jumper wire to the service check connector (Figure 12-43). This connects the two wires together in the service check connector. When the ignition switch is turned on, the EPS light begins to flash DTCs. Each DTC is indicated by a long light flash or flashes followed by a short flash or flashes. For example, DTC 11 is one long flash followed by a short flash, and DTC 12 is one long flash followed by two short flashes (Figure 12-44).

SERVICE TIP:
If the special jumper wire is left in the EPS service connector and the engine is started, the malfunction indicator light (MIL) for the engine computer system is illuminated.

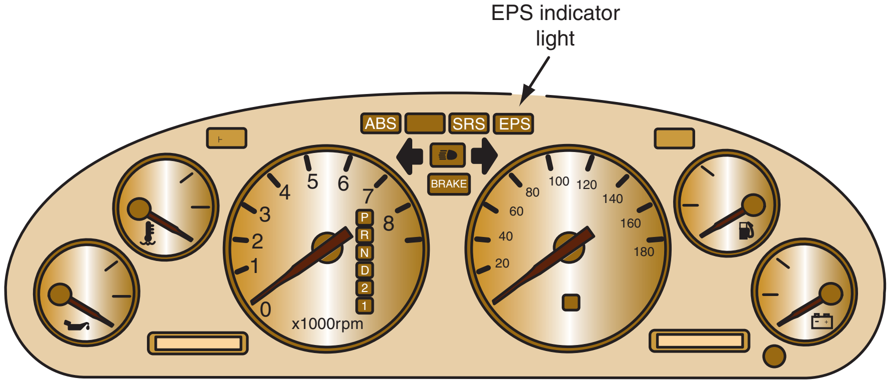


FIGURE 12-42 **Electronic power steering (EPS) warning light.**

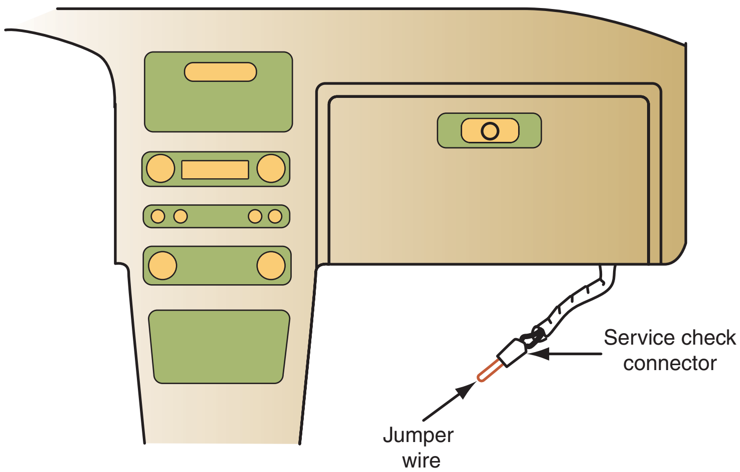


FIGURE 12-43 **EPS system service check connector and special jumper wire.**

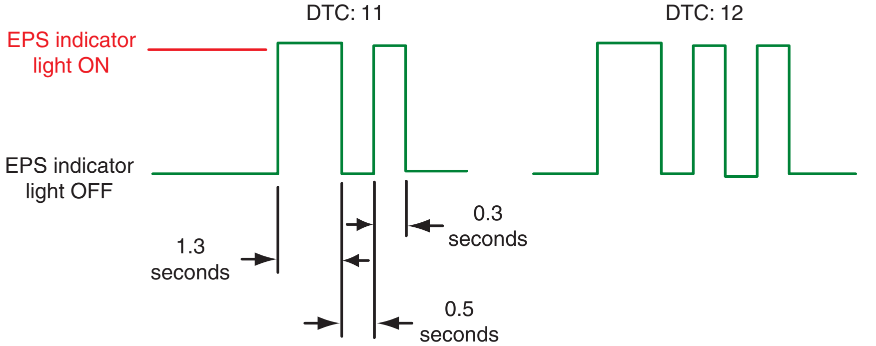


FIGURE 12-44 **DTC 11 is one long flash followed by a short flash, and DTC 12 is one long flash followed by two short flashes.**

SERVICE TIP: If DTC 33 is set in the EPS control unit memory, the EPS system remains functional, but the EPS light is illuminated.

If more than one DTC is stored in the EPS control unit memory, these DTCs are flashed in numerical order. The DTC sequence continues until the ignition switch is turned off. Be sure to remove the special jumper wire after the ignition switch is turned off.

All the possible DTCs in the EPS system are provided in Figure 12-45. A DTC indicates a defect in a certain area. For example, DTC 11 indicates high or low voltage from the torque sensor. The defect may be in the sensor itself, or the problem could be in the connecting wires from the sensor to the control unit. Tests usually have to be performed with a voltmeter or ohmmeter to locate the exact cause of the defect. Detailed diagnostic charts are provided in the car manufacturer's service manual.

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CUSTOMER CARE: Diagnosing automotive problems is an extremely important part of a technician's job on today's high-tech vehicles. Always take time to diagnose a customer's vehicle accurately. Fast, inaccurate diagnosis of automotive problems leads to unnecessary, expensive repairs and unhappy customers, who may take their business to another shop. Accurate diagnosis may take more time, but in the long term it will improve customer relations and bring customers back to the shop.

Diagnostic trouble code (DTC)	EPS indicator light	Description/symptom	Diagnostic period			After detecting for system	Reset	Individual diagnosis
			Individual diagnosis	Individual diagnosis	Regular diagnosis		Individual diagnosis	
—	○	EPS indicator light does not come on when ignition is switched ON						17 – 27
—	○	EPS indicator light does not go off after engine is started				System OFF		17 – 29
3	○	A problem with the current sensor offset	○			^		17 – 36
4	○	A problem with the current sensor offset	○	○		^	○	
5	○	A problem with the current sensor fixed		○		^	○	
6	○	A problem with the current sensor fixed		○		^	○	
11	○	A problem the high voltage with or low voltage of the torque sensor (TRQ1 and TRQ2)		○		^	○	17 – 31
12	○	A problem with the voltage for torque sensor (TRQ3)		○		^	○	
13	○	A problem with the average of voltage on TRQ1 and TRQ2		○		^	○	
14	○	A problem with the 2.5-V reference voltage		○		^	○	
21	○	A problem with the circuit for the input motor voltage in the EPS control unit	○	○	○	^	○	17 – 36
22	○	A problem with the lower current			○	^	○	
23	○	A problem with the circuit for check function in the EPS control unit	○	○		^	○	
24	○	The fail-safe relay or power relay is stuck ON	○			^	○	
25	○	The lower FET is stuck ON	○			^	○	
26	○	The upper FET is stuck ON	○			^	○	
31	○	A problem with the voltage for IG1	○	○		^	○	—
33	○	A problem with the average of VSS1 and VSS2			○	^	○	17 – 38
34	○	A problem with the CPU in the EPS control unit	○	○	○	^	○	Replace EPS control unit

- Initial diagnosis: Performed right after the engine starts until the EPS indicator light goes off.
- Regular diagnosis: Continuously performed (under some conditions) after the EPS indicator goes off and engine is running.
- Individual part/system diagnosis: Diagnoses a specific part/system under its operating conditions.
- CPU: Central Processing Unit.

FIGURE 12-45 **DTC list for EPS system.**

Diagnosis of Column-Drive Electronic Power Steering

When diagnosing a **column-drive EPS**, the first step is to verify the customer complaint. Road test the vehicle if necessary to be sure the complaint is identified. The next step is to perform a visual inspection of the EPS using the following steps:

1. Inspect all EPS electrical connections for corrosion or looseness including ground connections.
2. Inspect EPS wiring for damaged insulation.
3. Be sure the vehicle is equipped with the vehicle manufacturer's specified tire and wheel sizes.
4. Inspect the steering column and EPS components for collision damage.
5. Be sure the battery is fully charged and that the battery connections are clean and tight.
6. Check all the EPS fuses.
7. Inspect the vehicle for aftermarket accessories such as stereo equipment that could affect the EPS operation if they are improperly installed.
8. Search for service bulletins related to the EPS complaint.

SERVICE TIP:
When connecting certain scan tools to controller area network (CAN) or local area network (LAN) data link systems, a CANdi module must be connected in series between the scan tool and the DLC. Always refer to the vehicle manufacturer's recommended procedure.

Repair any problems discovered during the visual inspection. If the visual inspection did not locate any problems, perform a diagnostic system check using the following procedure:

1. Be sure the ignition switch is off, and connect a scan tool to the DLC under the left side of the dash.
2. Turn on the ignition switch, and select Vehicle DTC Information on the scan tool. If the scan tool displays No Comm. From Any Computer, repair the data link communication problem by referring to the appropriate diagnostic procedure in the vehicle manufacturer's service manual.
3. Be sure the engine cranks and starts properly.
4. Turn on the ignition switch with the engine stopped, and select List All DTCs on the scan tool.
5. Record all DTCs displayed on the scan tool. Check for DTCs from other computer systems that may affect the EPS system. For example, a DTC representing the VSS is displayed as a PCM DTC, but this sensor signal is transmitted on the data links to the PSCM and affects EPS operation.

Repair the causes of the DTCs displayed on the scan tool. Some typical EPS DTCs are:

1. C0460 steering position sensor
2. C0475 electric steering motor circuit
3. C0545 steering wheel torque input sensor
4. C0870 PSCM voltage range performance

On-Board Diagnostic II (OBD II) systems are a type of computer system mandated on cars and light trucks since 1996. OBD II systems have a number of mandated standardized features including several monitoring systems in the PCM.

In these **On-Board Diagnostic II (OBD II)** DTCs the first letter C indicates the DTC is related to a chassis problem. If the second digit in the DTC is a 0, the DTC is a universal Society of Automotive Engineers (SAE) code. When the second digit in the DTC is a 1, a vehicle manufacturer's code is indicated. The third digit in the DTC indicates the sub-system to which the DTC belongs, and the last two digits indicate the specific area where the fault exists. A complete list of DTCs is provided in the vehicle manufacturer's service manual. Some scan tools provide an explanation of each DTC indicating the area where the problem is located. A DTC indicates only the area in which a problem exists. Voltmeter and ohmmeter tests may be required to test the circuit and locate the exact cause of the problem. The vehicle manufacturer's service manual also provides a detailed diagnostic procedure for each DTC. Always follow these diagnostic procedures when diagnosing the cause of a DTC.

Scan Tool Data Display

The scan tool also displays the following EPS data which are very helpful when diagnosing EPS defects:

1. Battery voltage – The scan tool displays 6.5 V to 16.5 V as sensed at the power steering control module.
2. Calculated system temperature – The ambient temperature up to 275° F (135° C) as sensed by an internal temperature sensor in the PSCM.
3. Motor command – The amount of EPS assist motor current commanded by the PSCM.
4. Steering shaft torque – The amount of torque being applied to the steering column shaft. A positive value indicates a right turn, and a negative number indicates a left turn.
5. Steering position sensor voltage 1 – The amount of steering position sensor voltage from the sensor signal 1 circuit. The voltage range is 0 V to 5 V as the steering wheel is turned.
6. Steering position sensor voltage 2 – The amount of steering position sensor voltage from the sensor signal 2 circuit. The voltage range is 0 V to 5 V as the steering wheel is turned.
7. Steering tuning – The scan tool displays 1 or 2 depending on the vehicle. Steering tuning 1 is for 4-cylinder engines, and steering tuning 2 is for 6-cylinder engines. Steering tuning 3 is for the extended sedan.

8. Steering wheel position – The scan tool displays from 562° to −562° indicating the number of degrees the steering wheel has been turned for the center position. A positive number indicates a right turn, and a negative number indicates a left turn.
9. Torque sensor signal 1 – The scan tool displays 0.25 V to 4.75 V indicating the voltage from the steering shaft torque sensor 1 circuit.
10. Torque sensor signal 2 – The scan tool displays 0.25 V to 4.75 V indicating the voltage from the steering shaft torque sensor 2 circuit.
11. Vehicle speed – The actual vehicle speed from 0 to 158 mph (255 km/h).

Steering Position Sensor Calibration

If the PSCM or steering column is replaced, use the scan tool to calibrate the center position of the steering wheel position sensor as follows:

1. Be sure the ignition switch is off, and connect the scan tool to the DLC.
2. Turn on the ignition switch, but do not start the engine.
3. Turn the steering wheel from lock-to-lock and count the number of turns. From the fully left or fully right position, turn the steering wheel back toward the center position one-half the total number of turns.
4. Select Special Functions on the scan tool.
5. Select Steering Position Sensor Calibration on the scan tool and press the enter key. The scan tool screen indicates Calibration in Progress during the calibration procedure.
6. When the calibration process is completed, and the scan tool displays Calibration Completed, press the exit key.
7. Use the scan tool to clear any DTCs.
8. Turn off the ignition switch and disconnect the scan tool.

SERVICE TIP: After the ignition switch is turned off, wait 25 seconds before performing any procedures that require disconnecting the vehicle battery. If this precaution is not observed, the PSCM memory may be erased. This precaution also applies to torque sensor calibration and steering tuning selection.

Torque Sensor Calibration

If the PSCM or steering column is replaced, a scan tool must be used to perform a center position calibration for the steering shaft torque sensor as described in the following steps:

1. Be sure the ignition switch is off, and connect the scan tool to the DLC.
2. Turn on the ignition switch, but do not start the engine.
3. Turn the steering wheel from lock-to-lock and count the number of turns. From the fully left or fully right position, turn the steering wheel back toward the center position one-half the total number of turns.
4. After the steering wheel is centered, remove your hands or any other objects from the steering wheel. Be sure the suspension is relaxed, and that no uneven force is applied to the steering system.
5. Select Special Functions on the scan tool.
6. Select Torque Sensor Calibration on the scan tool and press the enter key. The scan tool screen indicates Calibration in Progress during the calibration procedure.
7. When the calibration process is completed, and the scan tool displays Calibration Completed, press the exit key.
8. Use the scan tool to clear any DTCs.
9. Turn off the ignition switch and disconnect the scan tool.

If the PSCM and motor assembly is removed from the steering column, inspect the steering column assist mechanism input shaft for the rotor isolator bumper (Figure 12-46). If present, the isolator bumper should be removed from the input shaft, and this bumper must be installed in the rotor isolator in the PSCM and motor assembly. Remove any debris from the steering column assist mechanism housing, but do not remove the remaining grease on the steering column assist mechanism input shaft.

SERVICE TIP: The combination steering wheel position sensor and steering shaft torque sensor are not serviced separately; the steering column and these two sensors are replaced as an assembly. The PSCM and motor can be replaced as an assembly separate from the steering column.

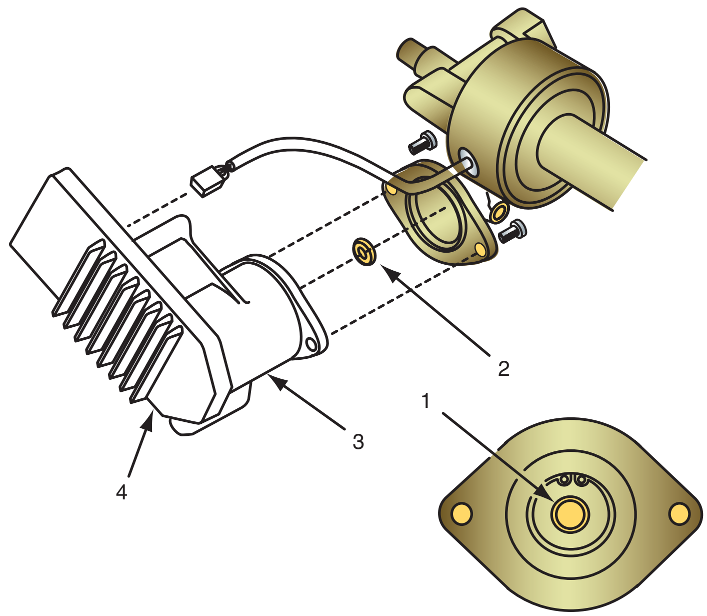

FIGURE 12-46 **Removing and replacing the PSCM and motor assembly.**

Steering Tuning Selection

If the PSCM is replaced, these steps must be followed to perform a steering tuning procedure:

1. Be sure the ignition switch is off, and connect the scan tool to the DLC.
2. Turn on the ignition switch, but do not start the engine.
3. Select Special Functions on the scan tool.
4. Select Steering Tuning Selection on the scan tool and press the enter key. The scan tool screen indicates Selection in Progress during the selection procedure.
5. When the selection process is completed, and the scan tool displays Selection Completed, press the exit key.
6. Use the scan tool to clear any DTCs.
7. Turn off the ignition switch and disconnect the scan tool.

Active Steering System Preliminary Diagnosis

The active steering system has a warning light and a service light in the instrument panel (Figure 12-47). When the active steering system is operating normally, the active steering warning light and service light go out after the engine starts. If an electronic defect occurs in the active steering system, the warning and service lights are illuminated. The service light indicates that a service message is available in the central information display screen in the instrument panel. When “service” is selected in the central information display screen, the following messages may be displayed:

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1. Active steering! Exercise care when steering.
   Active steering fault.
   Steering behavior altered. Steering wheel might be at an angle. Possible to continue journey with caution. Exercise care when steering. Have the problem checked by the nearest BMW service.
2. Active steering inactive.
   Active steering.
   Active steering inactive.
   Steering behavior altered. Steering wheel might be at an angle. Possible to continue journey with caution. Exercise care when steering.

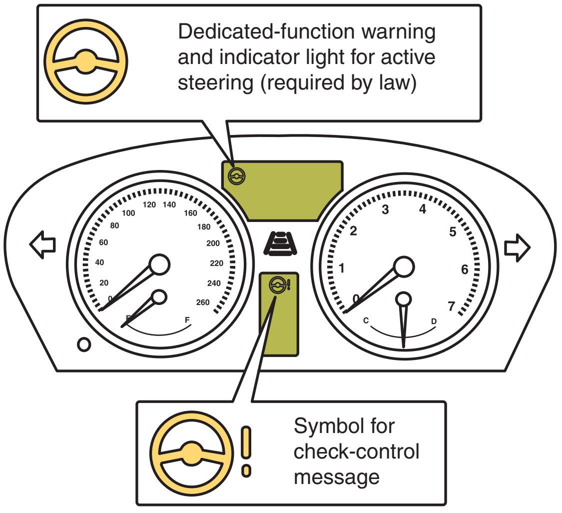

FIGURE 12-47 **Active Steering System light.**

3. Servotronic failure!
   Servotronic failure.
   Possible to continue journey with caution.
   Important: Power steering assistance is no longer automatically adapted to the vehicle's speed.
   Have problem checked by the nearest BMW service.

Preliminary Inspection

If the active steering warning lights are illuminated indicating a defect in the system, the first step in the diagnostic procedure is to perform a visual inspection of all system components, wiring, and fiber-optic cables. During the preliminary inspection, check these items:

1. Check the power steering fluid level and condition.
2. Inspect all wiring harness and electrical connectors in the system for damage, corrosion, and frayed insulation.
3. Inspect all fiber-optic cables for sharp bends, heat damage, punctures, cuts, or looseness.
4. Check all the hydraulic lines and fittings for damage or leaks.
5. Inspect all system mounting bolts for looseness.

Fiber-Optic Cable Service

Many vehicles with active steering have fiber-optic cable networks. **Media oriented systems transport (MOST) networks** have green fiber-optic cables, and **intelligent safety and integration systems (ISIS) networks** have yellow fiber-optic cables. Some manufacturers provide orange fiber-optic cables for repair purposes. Fiber-optic cables should always be inspected for sharp bends, heat damage, punctures or cracks, and loose connectors. Repair or replace fiber-optic cables as necessary. To remove a fiber-optic cable from a connector, follow this procedure:

1. To remove the connector, use a small screwdriver in the connector openings (Figure 12-48), and expand the cover catches. Remove the cover.
2. To remove the fiber optic cable from the connector lift the lock (Figure 12-49) and carefully feed the fiber optic cable out of the connector.
3. To install the fiber-optic cable in the connector, push the cable all the way into the connector and be sure the lock secures the cable.

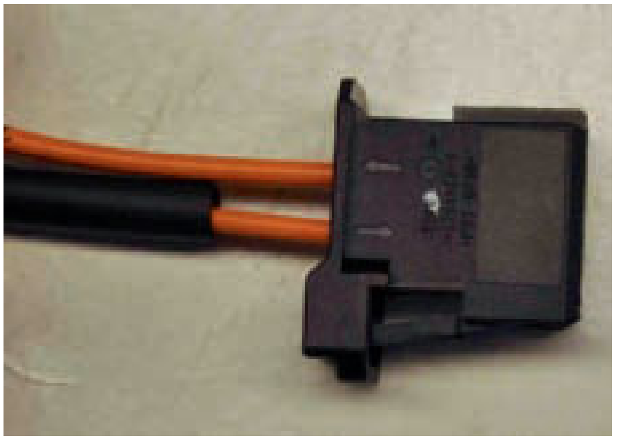

FIGURE 12-48 **Removing cover on a fiber-optic connector.**

FIGURE 12-49 **Removing a fiber-optic cable from a connector.**

FIGURE 12-50 **Removing a fiber-optic connector from its mounting surface.**

4. If it is necessary to remove the fiber optic cable from its mounting position press to release the lock in the bore (Figure 12-50) and remove the cable connector.

Active Steering Diagnosis System

A diagnosis system is supplied by the vehicle manufacturer (Figure 12-51). The diagnosis system is connected to the vehicle DLC, and this system is used for all coding, programming, and diagnosis of the active steering system and other systems. ECU and module replacement nearly always requires coding/programming of the replacement ECU or module. After the diagnosis system is connected to the DLC, to access the active steering system, select "Service functions," "Suspension," and "Active steering" on the diagnosis system menus. Always follow the vehicle manufacturer's recommended service, diagnosis, or programming procedure when using the diagnosis system.

If an electronic defect occurs in the active steering system, the diagnosis system displays DTCs. As in other electronic systems, the DTCs represent defects in a certain area, and voltmeter or ohmmeter tests may have to be performed to locate the root cause of the

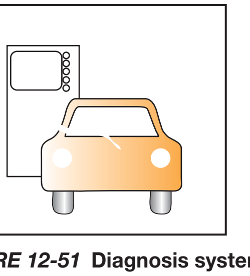

FIGURE 12-51 **Diagnosis system.**

problem. The technician must select the appropriate ECU to access the DTCs. For example, the **servotronic valve** and the **electronically controlled orifice (ECO) valve** are controlled by the **safety and gateway module (SGM)** on some models. Therefore, DTCs representing electronic faults in these valves are stored in the SGM, and the technician must access the SGM in the diagnosis system to obtain these DTCs. On other models, the servotronic valve and ECO valve are controlled by the **active steering ECU**, and DTCs representing defects in these components are stored in this ECU.

Certain service procedures and specific adjustments must be performed using the diagnosis system. For example, a steering angle sensor adjustment must be performed after any of the following procedures:

1. Adjustment procedures on the front steering or suspension.
2. Disconnecting the battery.
3. Any replacement of steering components.
4. Replacement of steering column sensors or switches.
5. Replacement of **dynamic stability control (DSC) ECU, active roll stabilization (ARS) ECU**, or active steering ECU.

When the active steering system is accessed in the diagnosis system, the steering angle sensor adjustment procedure is entered by selecting "Initial operation/adjustment for active front steering." Follow the vehicle manufacturer's recommended procedure in the diagnosis system to complete the steering angle sensor adjustment. Service and adjustment procedures may vary depending on the model and year of vehicle.

The need for a wheel alignment is indicated by any of the following conditions:

1. Inclination of the steering wheel from the straight ahead position with no faults stored in the active steering ECU memory.
2. Fault(s) stored in the active steering ECU memory and diagnosis system troubleshooting provides "Check wheel alignment" message.
3. Replacement of suspension and/or steering components that requires wheel alignment.

CASE STUDY

A customer complains about excessive steering effort on a 2008 Cadillac CTS. The technician road tested the car and found no evidence of hard steering. Further questioning of the customer revealed that the problem only occurred when the engine was first started in the morning after the car had been parked all night. The service writer informed the customer that the car would have to be parked overnight in the shop and then diagnosed the following morning. The customer complied with this request.

Prior to starting the engine the next morning, the technician connected a power steering pressure test gauge in series with the high-pressure hose. When the engine was started, the technician discovered the steering effort was very high, and the steering felt much like manual steering while the steering wheel was turned. However, the power steering pump pressure on the pressure gauge was higher than specified. Once the steering wheel was turned in one direction, the steering effort quickly decreased to normal. Since the power steering pump pressure was higher than specified, the technician concluded the pump and drive belt must be in satisfactory condition. The technician also reasoned that other causes of excessive steering effort, such as binding in the steering column or flexible coupling, would be constant. Therefore, the technician decided that the problem must be in the steering gear.

After receiving the customer's approval to remove and inspect the steering gear, the gear was removed and disassembled. The technician found the rack cylinder was severely ridged and scored in the center area, and the Teflon ring on the rack piston was badly worn. The customer was advised that the steering gear required replacement. A replacement steering gear was installed, and the system was flushed and refilled with power steering fluid. When the engine was started, the steering effort and the power steering pump pressure were normal.

Terms to Know

Active roll stabilization (ARS) ECU
Active steering ECU
Bellows boots
Bump steer
Claw washers
Column-drive EPS
Dynamic stability control (DSC) ECU
Electronically controlled orifice (ECO) valve
On-board diagnostic II (OBD II)
Rack-drive electronic power steering
Safety and gateway module (SGM)
Servotronic valve
Soft-jaw vise
Steering effort imbalance
Steering wheel free play

ASE-Style Review Questions

1. While discussing steering wheel free play:
   Technician A says excessive steering wheel free play may be caused by a worn outer tie-rod end.
   Technician B says excessive steering wheel free play may be caused by loose steering gear mounting bushings.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While discussing steering effort:
   Technician A says a tight rack bearing adjustment may cause excessive steering effort.
   Technician B says a loose inner tie-rod end may cause excessive steering effort.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. While discussing steering gear removal and replacement on air-bag-equipped vehicles:
   Technician A says the steering column should be locked in the centered position to prevent air bag deployment.
   Technician B says the rack should be centered in the housing prior to steering gear installation.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. While discussing power rack and pinion steering gear adjustment:
   Technician A says the self-locking nut on the pinion shaft should be rotated to adjust the pinion shaft bearing preload.
   Technician B says the rack spring cap should be rotated to obtain the specified turning torque on the pinion shaft.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

5. When servicing an active steering system, a steering angle sensor adjustment is required after all of these service procedures EXCEPT:
   A. Replacement of the active steering ECU.
   B. Replacement of a fiber-optic cable in the MOST network.
   C. Replacement of the steering gear.
   D. Adjustment of front wheel camber and caster.

6. All of these statements about diagnosing and servicing power rack and pinion steering gears are true EXCEPT:
   A. The inner rack seal may be defective if oil leaks from the pinion end of the housing when the rack reaches the left inner stop.
   B. A leaking rack piston seal causes increased steering effort in one direction.
   C. Leaking Teflon rings on the rotary valve may increase steering effort in both directions.
   D. If the pinion shaft is removed, the pinion seal and the input shaft seal must be replaced.

7. When diagnosing and servicing power rack and pinion steering gears:
   A. The rack should not be held when the outer tie-rod ends are loosened on the rack.
   B. In some steering gears, claw washers lock the tie-rods in position on the rack.
   C. A straightedge must be used to check the rack for a bent condition.
   D. Bent tie-rods may be straightened in a hydraulic press and then reinstalled.

8. When diagnosing and servicing power rack and pinion steering gears:
   A. Teflon rings on the rack piston may be expanded by heating them with a propane torch.
   B. A bent rack may cause excessive steering wheel free play.
   C. A compressing tool may be used to compress the Teflon rings on the rotary valve prior to installation.
   D. A scored cylinder surface in the steering housing may cause excessive steering wheel kickback.

9. When diagnosing electronic power steering (EPS) systems:
   A. The EPS system enters the diagnostic mode when the ignition switch is cycled three times in a 5-second interval.
   B. If the EPS warning light is on with the engine shut off and the ignition switch on, there is a defect in the EPS system.
   C. The EPS warning light flashes diagnostic trouble codes (DTCs) in numerical order.
   D. The EPS control unit memory has the capability to store only one DTC.

10. When diagnosing electronic power steering (EPS) systems:
   A. The DTCs may be erased from the EPS control unit by disconnecting the stop light fuse for 10 seconds.
   B. A DTC indicates the exact cause of an electrical defect in the EPS system.
   C. If a DTC is stored in the EPS control unit memory, the EPS system is usually inoperative and manual steering is available.
   D. In the EPS diagnostic mode if the EPS warning light provides two long flashes followed by two short flashes, code 2 is indicated.

ASE Challenge Questions

1. While discussing power rack and pinion steering gears:

   Technician A says inner rack seal leaks can cause power rack and pinion steering to turn easier in one direction than another.

   Technician B says a hissing noise is normal when the steering is turned to the limit on either side.

   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. Wandering or poor straight-ahead tracking may be caused by all of the following EXCEPT:
   A. Worn or loose rack mounting bushings.
   B. Rack piston seal leaks.
   C. Steering gear off-center.
   D. Loose or worn tie-rod ends.

3. A customer says his front-wheel-drive car with power rack and pinion steering is hard to steer for several minutes the first time the car is driven during the day.

   Technician A says the cause of the problem could be a plugged spool valve spring.

   Technician B says the cause of the problem could be a scored steering gear cylinder.

   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. A front-wheel-drive car requires very heavy steering effort in the parking lot but seems not too bad on the highway. Tire pressure is fine. After checking the fluid and finding the level is OK, you should:
   A. Check the engine idle speed.
   B. Look for steering system leaks.
   C. Check the tie-rod ends.
   D. Inspect the rack for damage.

5. *Technician A* says an oil leak at one rack seal may result in oil leaking from both boots.

   Technician B says the inner rack seal is defective if oil leaks from the pinion end of the housing when the rack reaches the left internal stop.

   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

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Name ______________________________ Date ____________________

Inspect Manual or Power Rack and Pinion Steering Gear and Tie-Rods

Upon completion of this job sheet, you should be able to inspect manual or power rack and pinion steering gears and tie-rods.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-18: Inspect, replace, and adjust tie-rod ends (sockets), tie-rod sleeves, and clamps.

Tools and Materials

Tape measure

Describe the Vehicle Being Worked On:

Year __________ Make ______________ Model ________________________

VIN ________________________ Engine type and size ____________________

Make of steering gear ____

Procedure

Task Completed

1. With the front wheels straight ahead and the engine stopped, rock the steering wheel gently back and forth with light finger pressure, and measure the maximum steering wheel free play with a tape measure.

   Specified steering wheel free play ________________________________

   Actual steering wheel free play __________________________________

   State the necessary repairs to correct steering wheel free play.

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2. With the vehicle sitting on the shop floor and the front wheels straight ahead, have an assistant turn the steering wheel about 1/4 turn in both directions. Watch for looseness in the steering shaft and the flexible coupling or universal joints.

   Looseness in U-joints or flexible coupling: ☐ Satisfactory ☐ Unsatisfactory

   Looseness in steering shaft: ☐ Satisfactory ☐ Unsatisfactory

Task Completed

State the necessary repairs and explain the reasons for your diagnosis.

3. While an assistant turns the steering wheel about 1/2 turn in both directions, watch for movement of the steering gear housing in the mounting bushings.

Looseness in steering gear mounting bushings: ☐ Satisfactory ☐ Unsatisfactory

State the necessary repairs and explain the reasons for your diagnosis.

4. Grasp the pinion shaft extending from the steering gear and attempt to move it vertically. If there is steering shaft vertical movement, a pinion bearing preload adjustment may be required. When the steering gear does not have a pinion bearing preload adjustment, replace the necessary steering gear components.

Excessive pinion shaft vertical endplay: ☐ Satisfactory ☐ Unsatisfactory

State the necessary repairs and explain the reasons for your diagnosis.

5. Road test the vehicle and check for excessive steering effort. A bent steering rack, tight rack bearing adjustment, or damaged front drive axle joints in front-wheel-drive cars may cause excessive steering effort.

Steering effort: ☐ Satisfactory ☐ Excessive

State the necessary repairs and explain the reasons for your diagnosis.

6. Visually inspect the bellows boots for cracks, splits, leaks, and proper clamp installation. Replace any boot that indicates any of these conditions.

Task Completed

Condition of tie-rod bellows boots and clamps:

Left side boot: ☐ Satisfactory ☐ Unsatisfactory

Right side boot: ☐ Satisfactory ☐ Unsatisfactory

State the necessary repairs and explain the reasons for your diagnosis.

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7. Loosen the inner bellows boot clamps and move each boot toward the outer tie-rod end until the inner tie-rod end is visible. Push outward and inward on each front tire, and watch for movement in the inner tie-rod end. An alternate method of checking the inner tie-rod ends is to squeeze the bellows boots and grasp the inner tie-rod end socket. Movement in the inner tie-rod end is then felt as the front wheel is moved inward and outward. Hard plastic bellows boots may be found on some applications. With this type of bellows boot, remove the ignition key from the switch to lock the steering column, and push inward and outward on the front tire while observing any lateral movement in the tie-rod.

Condition of inner tie-rod ends:

Left side inner tie-rod end: ☐ Satisfactory ☐ Unsatisfactory

Right side inner tie-rod end: ☐ Satisfactory ☐ Unsatisfactory

State the necessary repairs and explain the reasons for your diagnosis.

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WARNING: Bent steering components must be replaced. Never straighten steering components because this action may weaken the metal and result in sudden component failure, serious personal injury, and vehicle damage.

8. Grasp each outer tie-rod end and check for vertical movement. While an assistant turns the steering wheel 1/4 turn in each direction, watch for looseness in the outer tie-rod ends. Check the outer tie-rod end seals for cracks and proper installation of the nuts and cotter pins. Cracked seals must be replaced. Inspect the tie-rods for a bent condition.

tie-rod and outer tie-rod end condition:

Left side tie-rod and outer tie-rod end condition: ☐ Satisfactory ☐ Unsatisfactory

Right side tie-rod and outer tie-rod end condition: ☐ Satisfactory ☐ Unsatisfactory

List the necessary repairs and explain the reasons for your diagnosis.

Instructor's Response

Name ______________________________ Date ____________________

Remove and Replace Manual or Power Rack and Pinion Steering Gear

Upon completion of this job sheet, you should be able to remove and replace manual or power rack and pinion steering gears.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task List B-8: Remove and replace rack and pinion steering gear; inspect mounting bushings and brackets.

Tools and Materials

Floor jack
Safety stands
Outer tie-rod end puller
Tape measure
Torque wrench
Power steering fluid

Describe the Vehicle Being Worked On:

Year __________ Make ______________ Model ________________________
VIN ________________________ Engine type and size ________________

Procedure

Task Completed

1. Place the front wheels in the straight-ahead position and remove the ignition key from the ignition switch to lock the steering wheel. Place the driver's seat belt through the steering wheel to prevent wheel rotation if the ignition switch is turned on. This action maintains the clock spring electrical connector or spiral cable in the centered position on air-bag-equipped vehicles.

   Are the front wheels straight ahead and steering wheel locked? ☐ Yes ☐ No

   Instructor check ____

2. Lift the front end with a floor jack and place safety stands under the vehicle chassis. Lower the vehicle onto the safety stands. Remove the left and right fender apron seals.

   Is the chassis properly supported on safety stands? ☐ Yes ☐ No

   Are the fender apron seals removed? ☐ Yes ☐ No

   Instructor check ____

3. Place punch marks on the lower universal joint and the steering gear pinion shaft so they may be reassembled in the same position.

   Are the pinion shaft and U-joint punchmarked? ☐ Yes ☐ No

   Instructor check ____

Task Completed

4. Loosen the upper universal joint bolt, remove the lower universal joint bolt, and disconnect this joint.

   Is the U-joint disconnected from pinion shaft? ☐ Yes ☐ No

   Instructor check ______________________________

5. Remove the cotter pins from the outer tie-rod ends. Loosen, but do not remove, the tie-rod end nuts.

   Are the outer tie-rod end nuts loosened? ☐ Yes ☐ No

   Instructor check ______________________________

6. Use a tie-rod end puller to loosen the outer tie-rod ends in the steering arms. Remove the tie-rod end nuts and remove the tie-rod ends from the arms.

   Are the outer tie-rod ends removed from the steering arms? ☐ Yes ☐ No

   Instructor check ______________________________

7. Use the proper wrenches to disconnect the high-pressure hose and the return hose from the steering gear. (This step is not required on a manual steering gear.)

   Are the high-pressure and return hoses disconnected from the steering gear? ☐ Yes ☐ No

   Instructor check ______________________________

8. Remove the four stabilizer bar mounting bolts.

   Are the stabilizer mounting bolts removed? ☐ Yes ☐ No

   Instructor check ______________________________

9. Remove the steering gear mounting bolts.

   Are the steering gear mounting bolts removed? ☐ Yes ☐ No

   Instructor check ______________________________

☐ 10. Remove the steering gear assembly from the right side of the car.

11. Position the right and left tie-rods the specified distance from the steering gear housing. Measure this distance with a tape measure.

   Are the right and left tie-rods positioned at equal distances from the steering gear housing? ☐ Yes ☐ No

   Instructor check ______________________________

☐ 12. Install the steering gear through the right fender apron.

13. Install the pinion shaft in the universal joint with the punch marks aligned. Tighten the upper and lower universal joint bolts to the specified torque.

   Are the punch marks on the pinion shaft and U-joint properly aligned? ☐ Yes ☐ No

   Instructor check ______________________________

   Specified U-joint bolt torque ______________________________

Task Completed

Actual U-joint bolt torque ____________________

Instructor check ____________________

14. Install the steering gear mounting bolts and tighten these bolts to the specified torque.

Specified steering gear mounting bolt torque ____________________

Actual steering gear mounting bolt torque ____________________

15. Install the stabilizer bar mounting bolts and torque these bolts to specifications.

Specified stabilizer mounting bolt torque ____________________

Actual stabilizer mounting bolt torque ____________________

16. Install and tighten the high-pressure and return hoses to the specified torque. (This step is not required on a manual rack and pinion steering gear.)

Specified high-pressure and return hose fitting torque ____________________

Actual high-pressure and return hose fitting torque ____________________

CAUTION: Do not loosen the tie-rod end nuts to align the cotter pin holes. This action causes improper torquing of these nuts.

17. Install the outer tie-rod ends in the steering knuckles, and tighten the nuts to the specified torque. Install the cotter pins in the nuts.

Specified outer tie-rod end nut torque ____________________

Actual outer tie-rod end nut torque ____________________

Are the cotter pins properly installed? ☐ Yes ☐ No

18. Tighten the outer tie-rod end jam nuts to the specified torque; then tighten the outer bellows boot clamps.

Specified outer tie-rod end jam nut torque ____________________

Actual outer tie-rod end jam nut torque ____________________

Are the bellows boot clamps properly installed and tightened? ☐ Yes ☐ No

Instructor check ____________________

19. Install the left and right fender apron seals; then lower the vehicle with a floor jack. ☐

20. Fill the power steering pump reservoir with the vehicle manufacturer's recommended power steering fluid, and bleed air from the power steering system. (This step is not required on a manual rack and pinion steering gear.)

Is the power steering pump reservoir filled to the specified level with the proper power steering fluid? ☐ Yes ☐ No

Is the air bled from the power steering system? ☐ Yes ☐ No

21. Perform a front wheel toe measurement, and adjust the toe as required.

Toe satisfactory ☐ Yes ☐ No

Toe adjustment performed ☐ Yes ☐ No

Instructor check ____________________

22. Road test the vehicle and check for proper steering gear operation and steering control.

Steering operation: ☐ Satisfactory ☐ Unsatisfactory

If the steering operation in unsatisfactory, state the necessary repairs and explain the reason for your diagnosis.

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Instructor's Response ____

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Name ______________________________ Date ____________________

Diagnose Power Rack and Pinion Steering Gear Oil Leakage Problems

Upon completion of this job sheet, you should be able to diagnose power rack and pinion steering gear oil leakage problems.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-5: Diagnose power steering gear (rack and pinion) binding uneven turning effort, looseness, hard steering, and noise concerns; determine necessary action.

Tools and Materials

Power steering fluid

Describe the Vehicle Being Worked On:

Year __________ Make ______________ Model ________________________

VIN ________________________ Engine type and size ____________________

Procedure

Task Completed

WARNING: If the engine has been running for a length of time, power steering gears, pumps, lines, and fluid may be very hot. Wear eye protection and protective gloves when servicing these components.

1. Be sure the power steering reservoir is filled to the specified level with the proper power steering fluid. ☐

2. Be sure the power steering fluid is at normal operating temperature. If necessary, rotate the steering wheel several times from lock-to-lock to bring the fluid to normal operating temperature.

   Is the power steering reservoir filled to the specified level? ☐ Yes ☐ No

   Is the power steering fluid at normal temperature? ☐ Yes ☐ No

   Instructor check ____

3. Inspect the cylinder end of the steering gear for oil leaks.

   Oil leaks at cylinder end of the power steering gear:

   ☐ Satisfactory ☐ Unsatisfactory

Task Completed

If there are oil leaks in this area, state the necessary repairs and explain the reasons for your diagnosis.

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SERVICE TIP:
An oil leak at one rack seal may result in oil leaks from both boots because the oil may travel through the breather tube between the boots.

4. Inspect the steering gear for oil leaks at the pinion end of the housing with the engine running and the steering wheel turned so the rack is against the left internal stop.

   Oil leaks at the pinion end of the steering gear with the rack against the left inner stop:

   ☐ Satisfactory ☐ Unsatisfactory

   If there are oil leaks in this area, state the necessary repairs and explain the reasons for your diagnosis.

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5. Inspect the pinion end of the power steering gear housing for oil leaks with the steering wheel turned in either direction.

   Oil leak at the pinion end of the housing with the steering wheel turned in either direction: ☐ Satisfactory ☐ Unsatisfactory

   If there are oil leaks in the area, state the necessary repairs and explain the reasons for your diagnosis.

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6. Inspect the pinion coupling area for oil leaks.

   Oil leaks in the pinion coupling area: ☐ Satisfactory ☐ Unsatisfactory

   If there are oil leaks in the area, state the necessary repairs and explain the reasons for your diagnosis.

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7. Inspect all the lines and fittings on the steering gear for oil leaks as an assistant turns the wheels with the engine running.

   Oil leaks at steering gear fittings: ☐ Satisfactory ☐ Unsatisfactory

   Oil leaks in steering gear hoses and lines: ☐ Satisfactory ☐ Unsatisfactory

If there are oil leaks in the power steering fittings, lines, or hoses, state the necessary repairs and explain the reasons for your diagnosis.

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8. With the engine running, turn the steering wheel fully in each direction and check the steering effort.

Steering effort in both directions: ☐ Normal ☐ Excessive

If the steering effort is not equal in both directions, state the direction in which steering effort is highest: ☐ Right ☐ Left

If the steering effort is excessive or unequal, state the necessary repairs and explain the reason for your diagnosis. ____

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Instructor's Response ____

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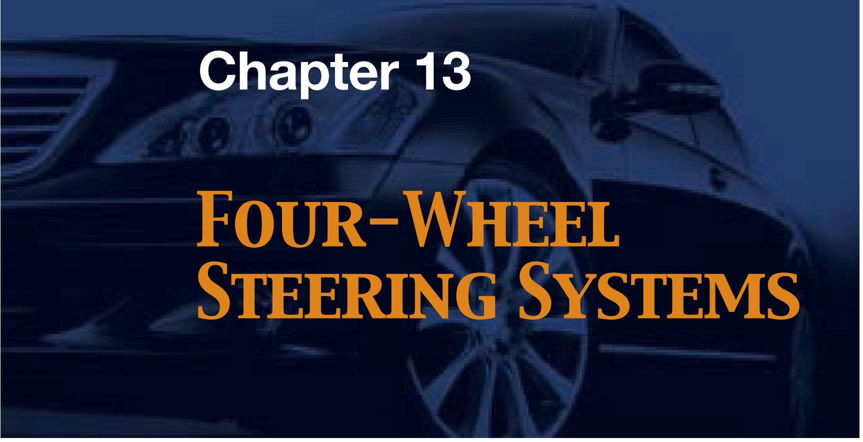

Chapter 13

Four-Wheel Steering Systems

Upon completion and review of this chapter, you should be able to understand and describe:

- The advantages of four-wheel steering (4WS).
- How the rear steering rack is driven in a Quadrasteer system.
- The two inputs used by the control unit to operate the rear steering in a Quadrasteer system.
- Why a higher output alternator is required on a vehicle equipped with Quadrasteer.
- Negative phase and positive phase steering in a Quadrasteer system.
- The advantages of a Quadrasteer system when towing a trailer.
- The input sensors in an electronically controlled four-wheel steering system and give the location of each sensor.
- The type of signal produced by a wheel speed sensor.
- The steering action of the rear wheels in relation to vehicle speed in an electronically controlled four-wheel steering system.
- The operation and advantages of rear active steering (RAS) and four-wheel active steering (4WAS).

Introduction

If a car with conventional front wheel steering is parallel parked at a curb between two vehicles, this car may be driven from the parking space without hitting the car in front if the front wheels are turned all the way to the left (Figure 13-1, view A). When the same car is equipped with 4WS and the rear wheels steer in the same direction as the front wheels at low speed, the car will not steer out of the parking space without striking the vehicle in front (Figure 13-1, view B).

When the car in the same parking space has a 4WS system that steers the rear wheels in the opposite direction to the front wheels at low speed, the car steers out of the parking space with plenty of distance between the vehicle parked in front (Figure 13-1, view C). When the rear wheels steer in the opposite direction to the front wheels, the rear wheels steer toward the curb. This action causes the right rear tire to strike the curb if the car is parked close to the curb. Therefore, the maximum rear **steering angle** must be considerably less than the maximum front wheel steering angle to help prevent this problem. A car with 4WS has a smaller **turning circle**, or turning radius, compared to a vehicle with conventional front wheel steering. This improves maneuverability while parking.

The rear wheel steering in a 4WS system may be controlled in relation to vehicle speed or the amount of steering wheel rotation. At low vehicle speeds or with a considerable amount of steering wheel rotation, the rear wheels are steered in the opposite direction to the front

Steering angle is the number of degrees that the wheels turn when steered.

Turning circle is the diameter of a circle completed by a vehicle when the front wheels are turned fully to the right or left.

A Bit of History

The **four-wheel steering (4WS)** concept has been researched by automotive engineers for several decades. In 1962, an engineer representing one of the Japanese manufacturers stated at the Japanese Automotive Engineering Asso ciation's technical meeting, "A major improvement in control and stability may be anticipated by means of an automatic rear wheel steering system." In the late 1970s, Honda and Mazda were actively engaged in 4WS development. However, it was not until the late 1980s that 4WS was introduced on a significant number of Honda and Mazda cars.

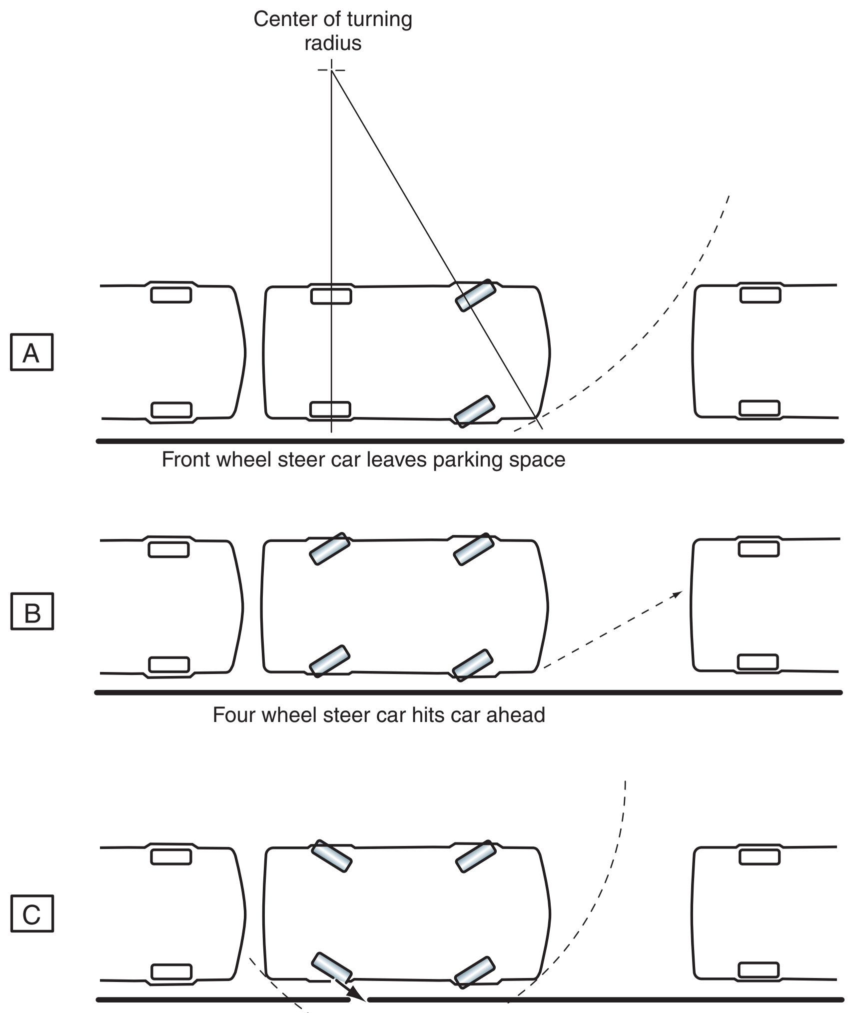

FIGURE 13-1 **Parallel parking with conventional front wheel steering and four-wheel steering.**

In a **four-wheel steering (4WS)** system all four wheels are turned to steer the vehicle.

wheels. When the vehicle is operating at higher speeds or with a small amount of steering wheel rotation, the rear wheels are steered in the same direction as the front wheels.

When a vehicle is cornering at higher speeds, centrifugal force tends to move the rear of the vehicle sideways. This action causes the rear tires to slip sideways on the road surface. This process may be called **sideslip**. The vehicle speed and the severity of the turn determine the amount of sideslip. If sideslip is excessive, the car may spin around, causing the driver to lose control. When the 4WS system steers the rear wheels in the same direction as the front wheels at higher speeds, sideslip is reduced and vehicle stability is improved. The higher speed same-direction steering angle is considerably less than the low-speed opposite-direction steering angle.

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Electronically Controlled Four-Wheel Steering

System Overview

In an **electronically controlled 4WS system**, rear wheel steering is controlled electronically.

Some cars are equipped with an **electronically controlled 4WS system**. On the electronically controlled 4WS system, there is no mechanical connection between the front steering gear and the **rear steering actuator**. This rear steering actuator is now controlled by

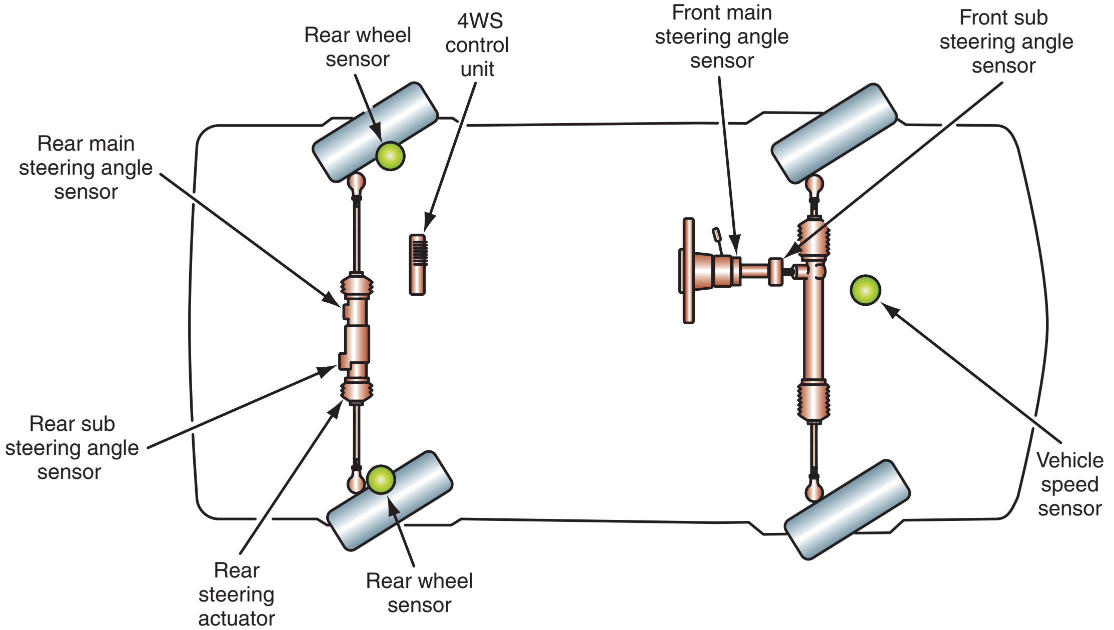

FIGURE 13-2 **Electronically controlled 4WS with control unit mounted in the trunk.**

a 4WS control unit mounted in the trunk behind the left rear seat (Figure 13-2). The 4WS control unit in the electronically controlled system uses steering wheel rotational speed, vehicle speed, and front steering angle information to calculate and control the rear steering angle.

Rear Steering Actuator

The rear steering actuator may be compared to an electric steering gear. This actuator contains an electric motor that drives a steering rack through a ball screw mechanism (Figure 13-3). Conventional tie-rods are connected from the steering actuator to the rear steering arms and spindles. A return spring inside the actuator moves the rear wheels to the straight-ahead

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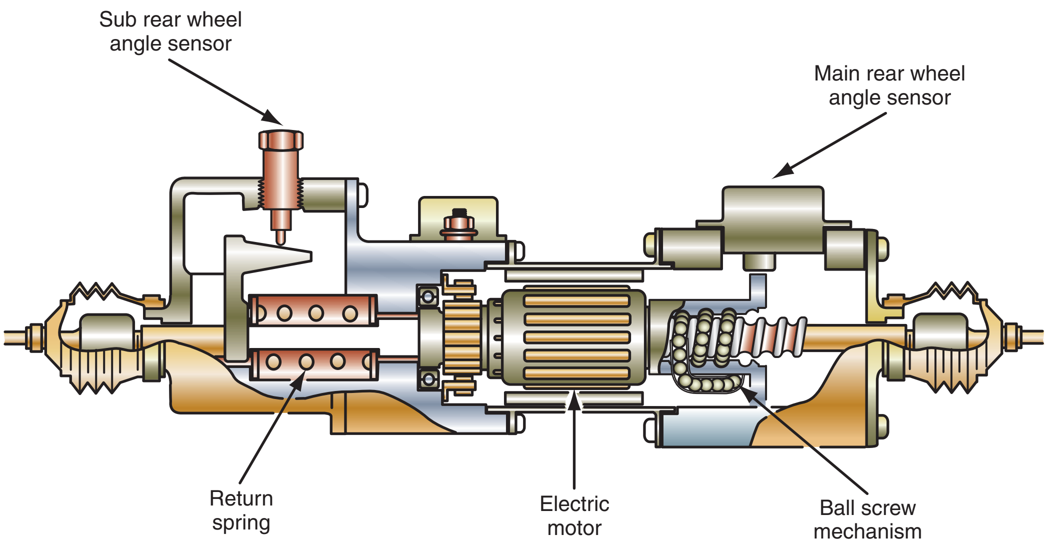

FIGURE 13-3 **Rear steering actuator, electronically controlled 4WS system.**

position when the ignition switch is turned off or when a defect occurs in the 4WS system. A main rear wheel angle sensor and a sub rear wheel angle sensor are mounted on top of the rear steering actuator.

CAUTION: Some electronic sensor wires have a special shield surrounding them to prevent electromagnetic interference (EMI) from other voltage sources. If this shield is damaged or removed, computer system operation may be adversely affected. Do not reroute sensor wires close to other voltage sources such as spark plug wires.

Input Sensors

Input sensors in the electronically controlled 4WS include the following:

1. Main rear wheel angle sensor in the rear steering actuator.
2. Sub rear wheel angle sensor in the rear steering actuator.
3. Main **steering wheel angle sensor** in the steering column under the combination switch.
4. Sub front wheel steering angle sensor in the front rack and pinion steering gear.
5. Conventional rear ABS wheel speed sensors.
6. Conventional vehicle speed sensor (VSS).

Four-Wheel Steering System Operation

4WS Control Unit Operation

When the engine is running, the 4WS control unit continually receives information from all the input sensors. If the steering wheel is turned, the 4WS control unit analyzes information from the vehicle speed sensor, main steering wheel angle sensor, sub front wheel angle sensor, main rear wheel angle sensor, sub rear wheel angle sensor, and the rear wheel speed sensors. The 4WS control unit calculates the proper rear wheel steering angle and then sends battery voltage to the rear steering actuator motor to provide this rear steering angle (Figure 13-4).

Transistors may be defined as automatic electronic relays that have no moving parts and are made from semiconductor materials.

Battery voltage is sent to the rear steering actuator motor through two heavy-duty output **transistors**. One of these transistors conducts current during a right turn, whereas the other transistor is activated during a left turn. The main rear wheel angle sensor and the sub

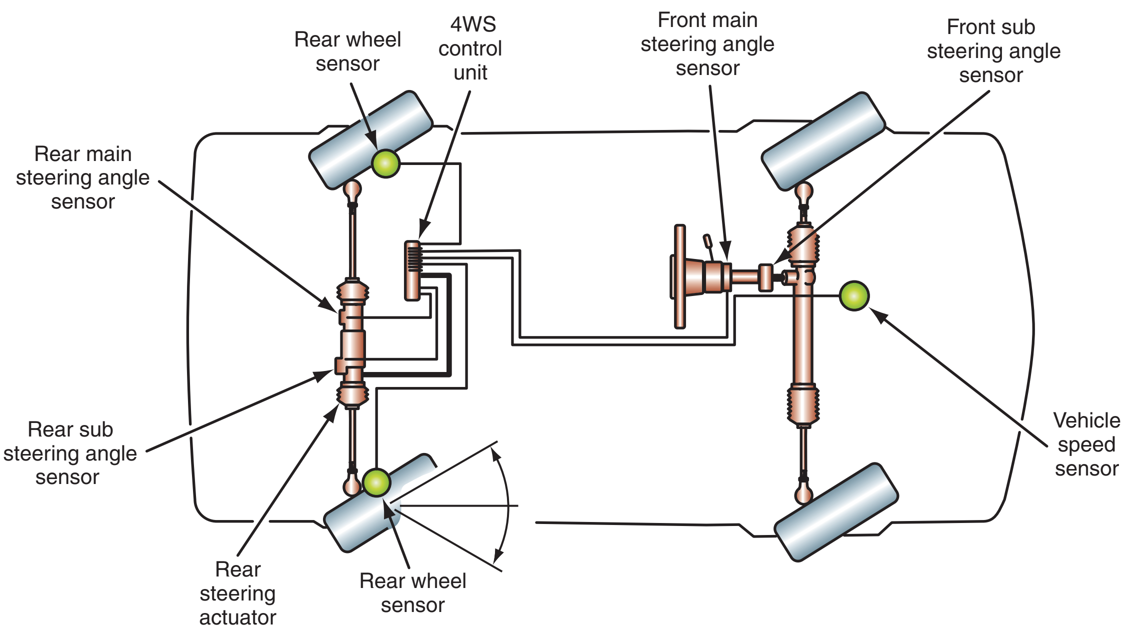

FIGURE 13-4 **The 4WS control unit analyzes input sensor information, calculates the required rear steering angle, and operates the rear steering actuator motor to provide the proper rear steering angle.**

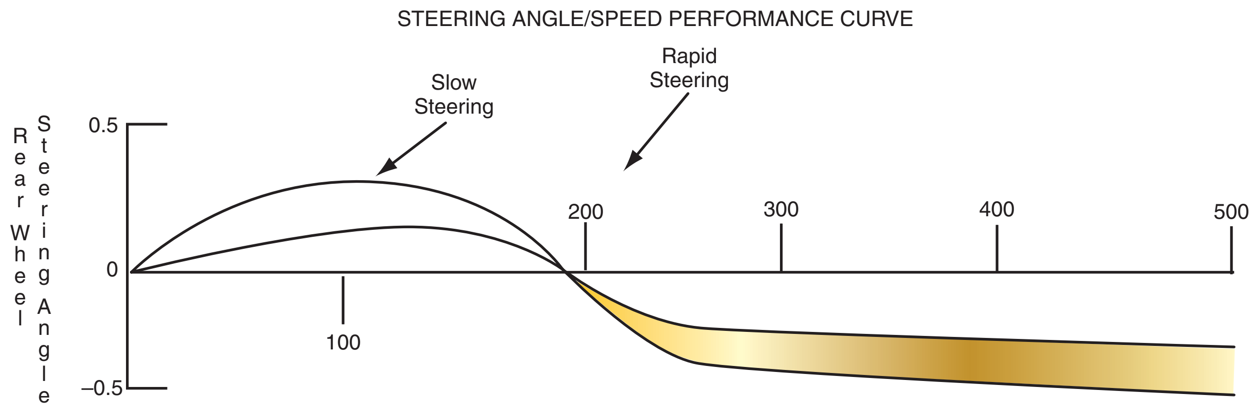

FIGURE 13-5 **Rear steering angle in relation to vehicle speed and steering wheel rotation.**

rear wheel angle sensor send feedback signals to the 4WS control unit, indicating the proper rear steering angle has been supplied.

4WS Operating Characteristics

When the vehicle speed is less than 18 mph (29 km/h), the rear wheels immediately begin to steer in the opposite direction to the front wheels if the steering wheel is turned (Figure 13-5). Maximum rear steering angle is 6° at 0 mph. The rate of rear steering angle decreases in relation to vehicle speed, and at 18 mph (29 km/h) the amount of rear steering angle is almost zero.

When the vehicle speed increases above 18 mph (29 km/h), the rear wheels steer in the same direction as the front wheels through the first 200° of steering wheel rotation. The rear steering angle reverts to the opposite phase if the steering wheel is rotated more than 200° in this vehicle speed range. When the vehicle speed is 60 mph (96 km/h) and the steering wheel rotation is 100°, the rear wheels steer about 1° in the same direction as the front wheels. If the steering wheel is rotated 500° slowly at this speed, the rear wheels are steered about 1° in the opposite direction to the front wheels.

Quadrasteer Four-Wheel Steering Systems

A **Quadrasteer** system is available on some light-duty trucks and SUVs. The Quadrasteer system is a four-wheel steering (4WS) system that improves low speed maneuverability, high speed stability, and towing capability. The Quadrasteer system has an electronically powered rear steering system. Vehicles with a Quadrasteer system require a higher output alternator because of the additional electrical load of the rear wheel steering actuator motor.

Rear Wheel Steering Control Module and Driver Select Switch

The rear wheel steering control module is mounted on the frame under the rear of the vehicle (Figure 13-6). This module controls all the rear wheel steering functions. A 125A mega fuse in an underhood fuse holder supplies voltage to the control module at all times (Figure 13-7). Battery voltage is also supplied to the control module from the 4WS fuse, and the control module receives ignition voltage through the 10A ignition fuse.

The rear wheel steering mode select switch is mounted in the instrument panel (Figure 13-8). The driver uses the rear wheel steering select switch to select 4WS, 2WS, or 4WS trailer mode. Each time the driver selects a rear wheel steering mode, an input signal is sent from the mode select switch to the control module (Figure 13-9). Light emitting diode (LED) indicators in the switch inform the driver regarding the selected rear wheel steering mode.

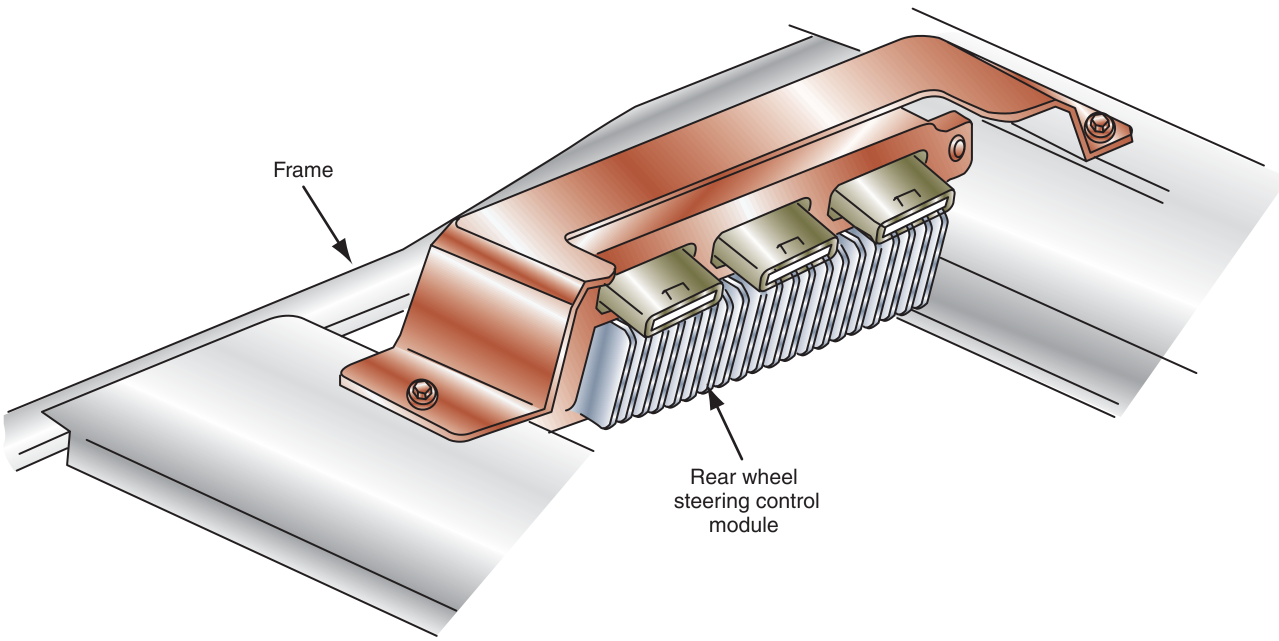

FIGURE 13-6 **Rear wheel steering control module.**

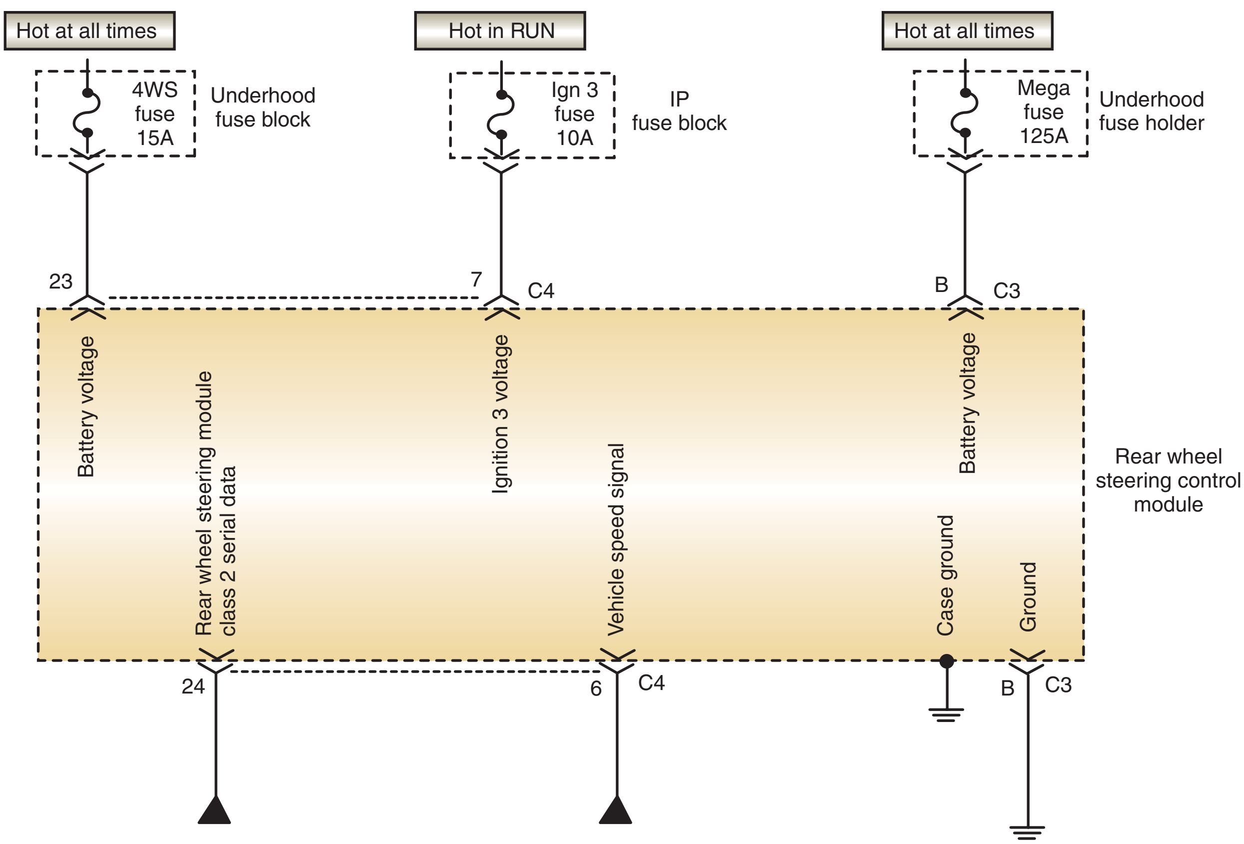

FIGURE 13-7 **Battery and ignition voltage inputs to the rear wheel steering control module.**

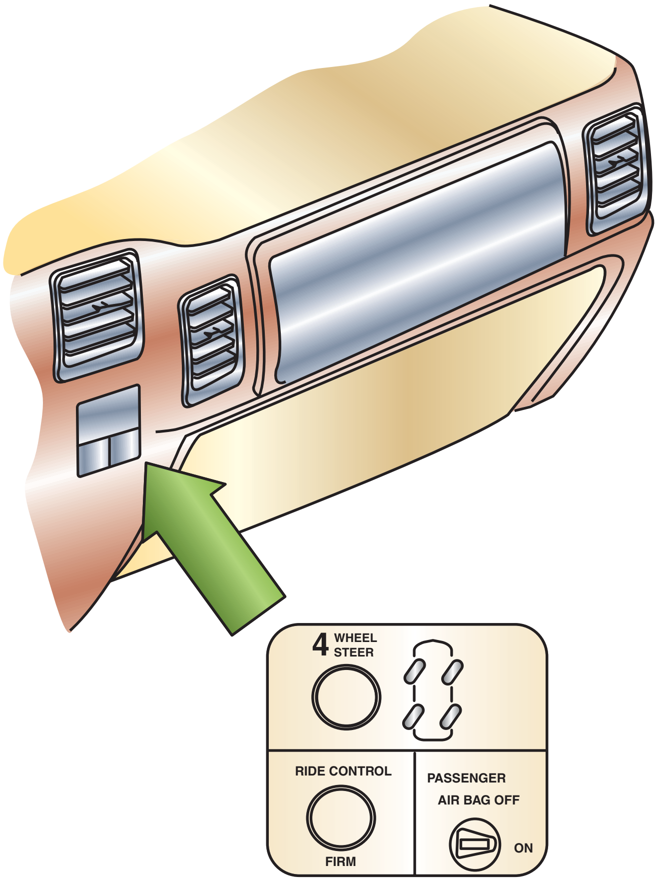

FIGURE 13-8 **Rear wheel steering mode select switch.**

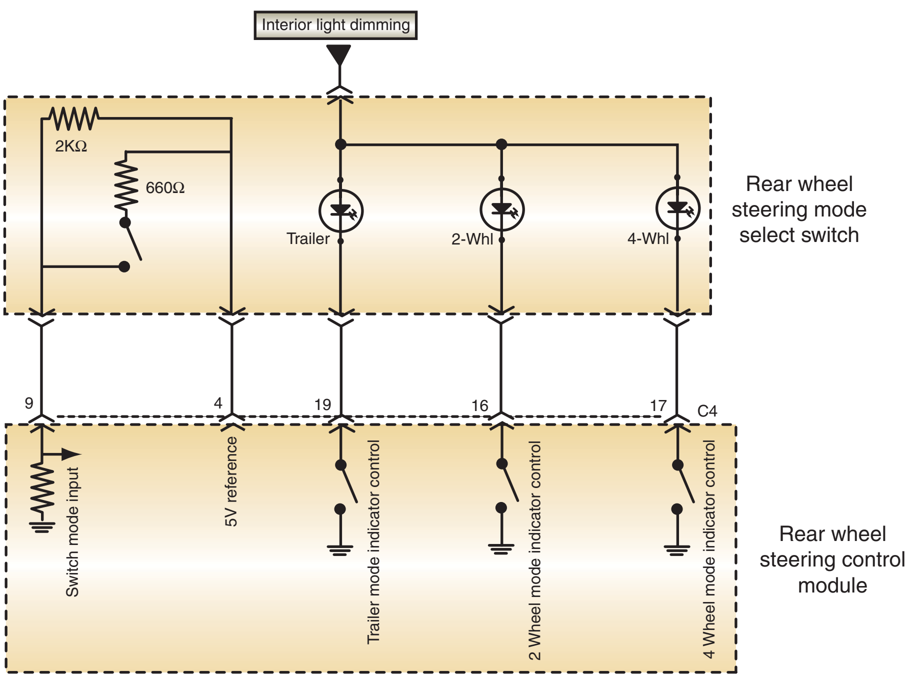

FIGURE 13-9 **Rear wheel steering mode select switch inputs to the control module.**

Steering Wheel Position Sensor

The steering wheel speed/position sensor (SWPS) is mounted at the lower end of the steering column and this sensor is controlled by steering shaft rotation (Figure 13-10). The steering wheel position sensor provides an analog signal and three digital signals to the control module. The body control module (BCM) supplies a 5 V reference signal to the SWPS, and a low reference or ground wire is also connected from the SWPS to the BCM. The SWPS contains a potentiometer, which sends an **analog voltage signal** to the BCM in relation to steering wheel rotation (Figure 13-11). The analog voltage signal from the SWPS to the BCM ranges

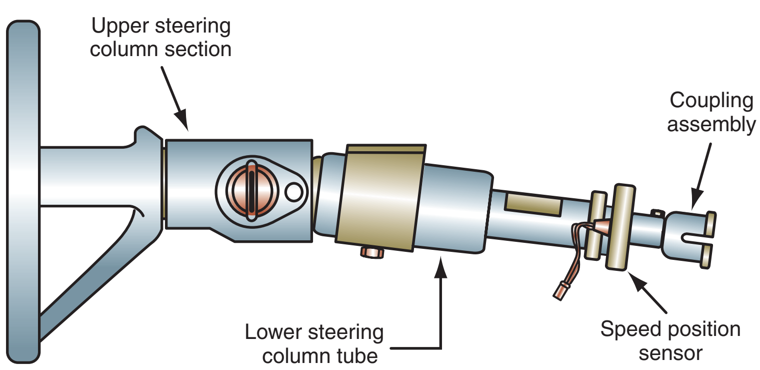

FIGURE 13-10 **Steering wheel speed/position sensor.**

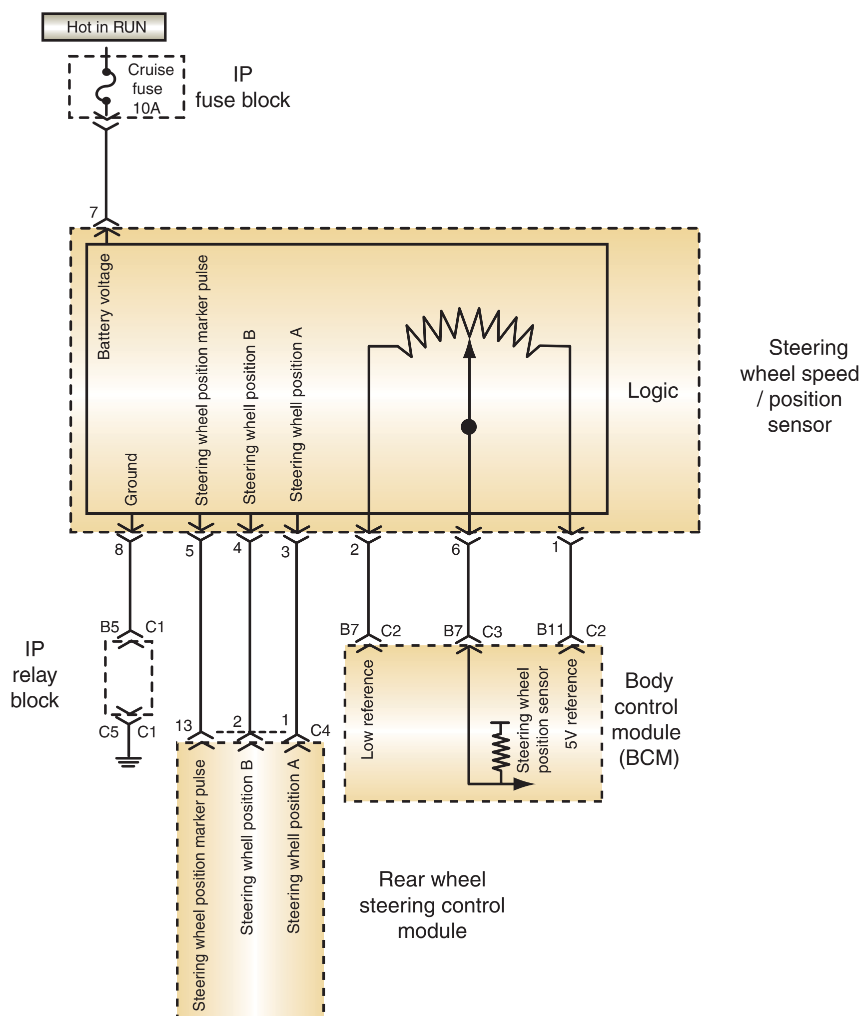

FIGURE 13-11 **SWPS inputs to the control module.**

from 0.25 V with the steering wheel positioned one turn to the left of the center position to 4.75 V when the steering wheel is positioned one turn to the right of the center position. With the steering wheel in the center position, the SWPS analog voltage signal is 2.5 V. When the steering wheel is turned more than one turn to the right of left of the center position, the SWPS signal does not change. The BCM relays the SWPS analog voltage signal through class 2 data links to the rear wheel steering control module.

The SWPS sends digital signals through the phase A, phase B, and marker pulse circuits directly to the control module. The marker pulse digital signal is displayed on a scan tool as High if the steering wheel is positioned between 10° to the left or 10° to the right of the center position. If the steering wheel is positioned more than 10° to the right or left of the center position, the pulse marker signal is displayed as Low. The phase A and phase B signals are displayed on a scan tool as High or Low as the steering wheel is rotated. These signals change from High to Low every one degree of steering wheel rotation.

Rear Wheel Position Sensor

The rear wheel position sensor is mounted on the lower side of the rear wheel steering gear (Figure 13-12). The rear wheel position sensor has two signal circuits connected to the rear wheel steering control module (Figure 13-13). The position 1 signal is a linear measurement of voltage per degree of rear steering position sensor rotation. For the position 1 input the measurement in degrees is from –620° to the left to +620° to the right. The voltage signal from the position 1 input is 0.25 V to 4.75 V. If the signal voltage from position 1 is 0.25 V, the steering wheel has been rotated –600° past center. When the signal voltage from position 1 is 4.75 V, the steering wheel has been rotated +600° past center. The voltage signal from position 2 increases or decreases from 0.25 V to 4.75 V every 180° of steering wheel rotation.

Rear Steering Gear

The rear steering gear is a rack and pinion–type gear mounted on the differential cover. The rack is connected through tie-rods and outer tie-rod ends to the steering knuckles. The outer tie-rod ends are threaded onto the tie-rods and retained with a jam nut. The inner ends of

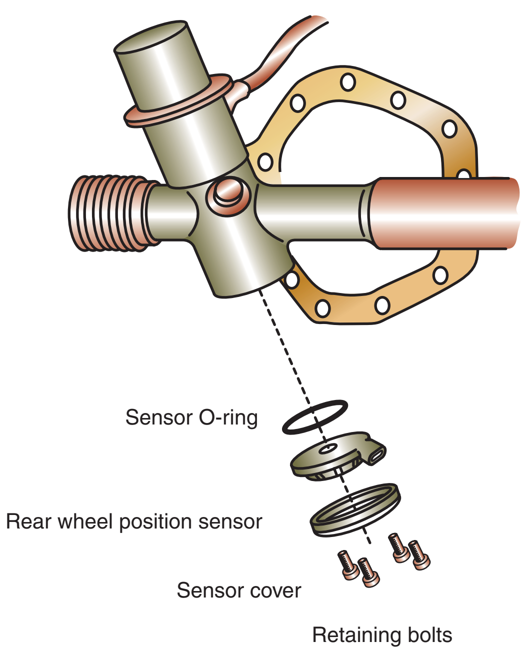

FIGURE 13-12 **Rear wheel position sensor.**

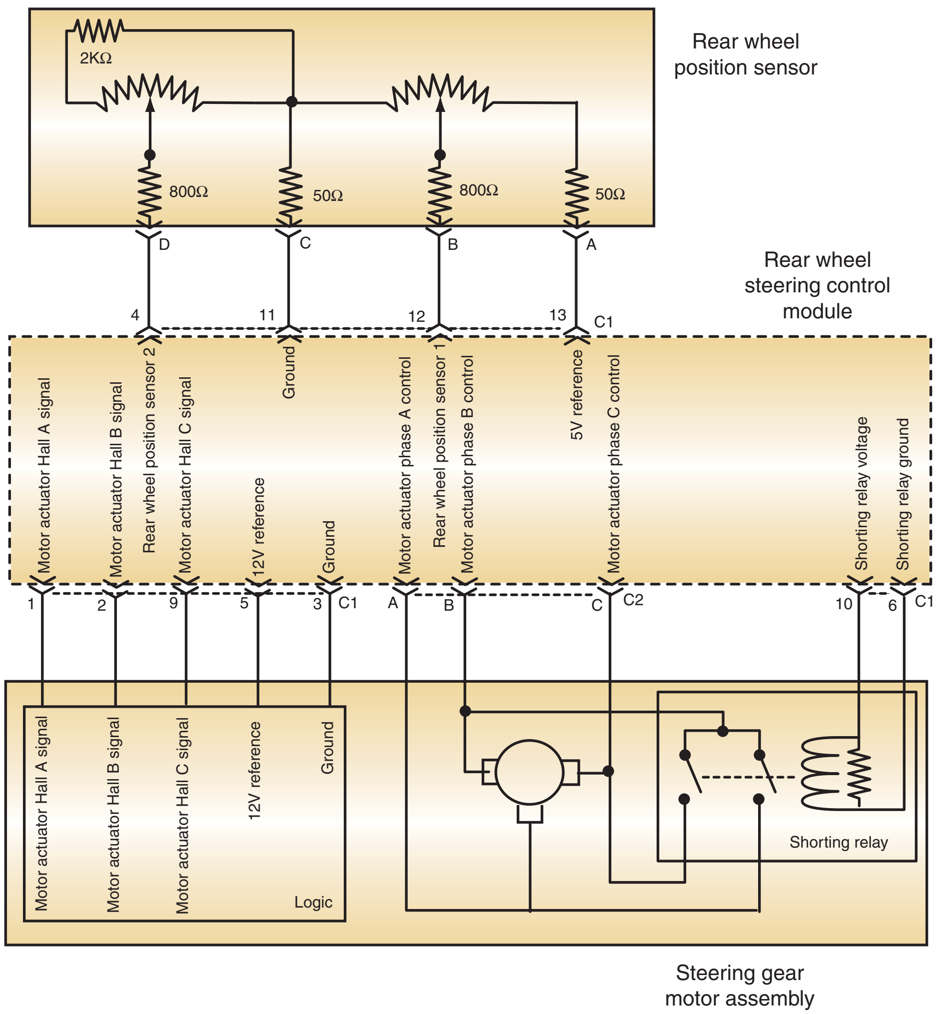

FIGURE 13-13 **Rear wheel position sensor inputs to the rear wheel steering control module.**

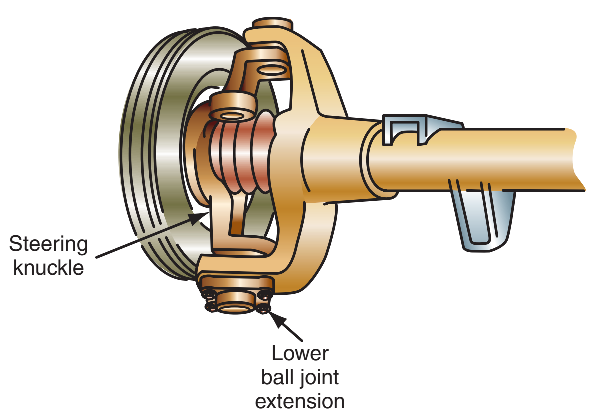

FIGURE 13-14 **Lower ball joint, rear wheel steering.**

the tie-rods are clamped to the ends of the steering gear rack. Special tools are required to remove and install the inner ends of the tie-rods on the rack. The steering knuckles pivot on upper and lower ball joints that are bolted into extensions on the differential housing (Figure 13-14). Constant velocity (CV) joints are mounted near the outer end of each rear axle shaft. Splined shafts extend from the outer side of the CV joints into the rear hub and

bearing assemblies that are bolted to the steering knuckles (Figure 13-15). A nut, lock, and cotter pin retain the outer ends of the splined shafts in the hub and bearing assemblies. The brake rotors are retained on the studs in the hub and bearing assemblies. The hub and bearing assemblies are not serviceable. The electric drive motor for the rear steering gear is mounted on the top of the steering gear, and this motor is protected by a shield and skid plate attached to the differential (Figure 13-16). The electric motor drives the steering gear rack to provide rear wheel steering. The maximum rear wheel steering angle is 12° in either direction.

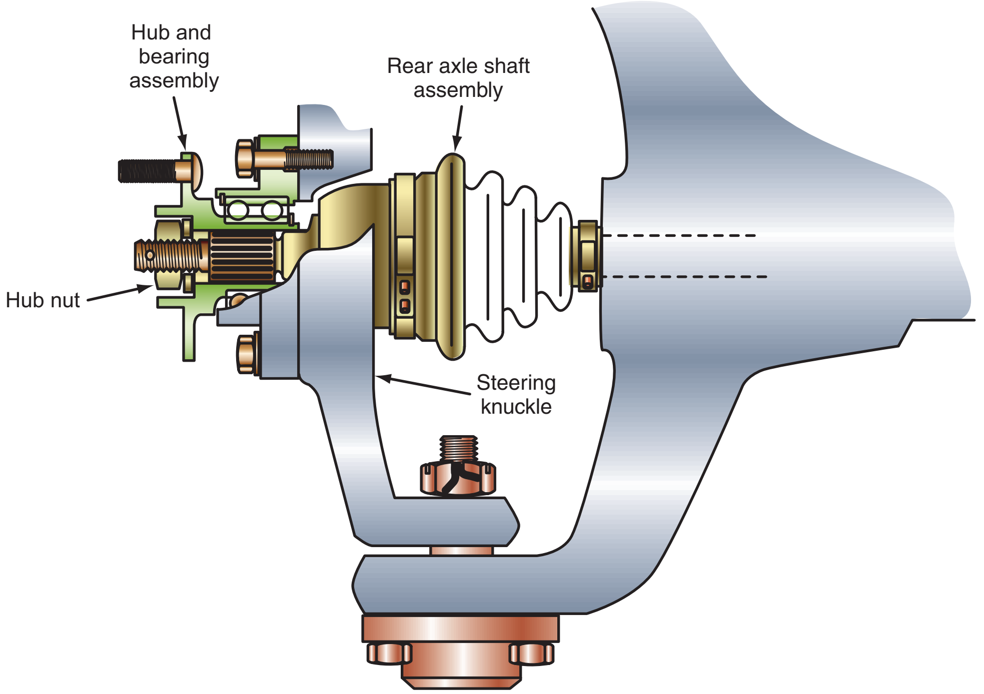

FIGURE 13-15 **Rear axle shaft, hub and bearing assembly, and knuckle, rear wheel steering.**

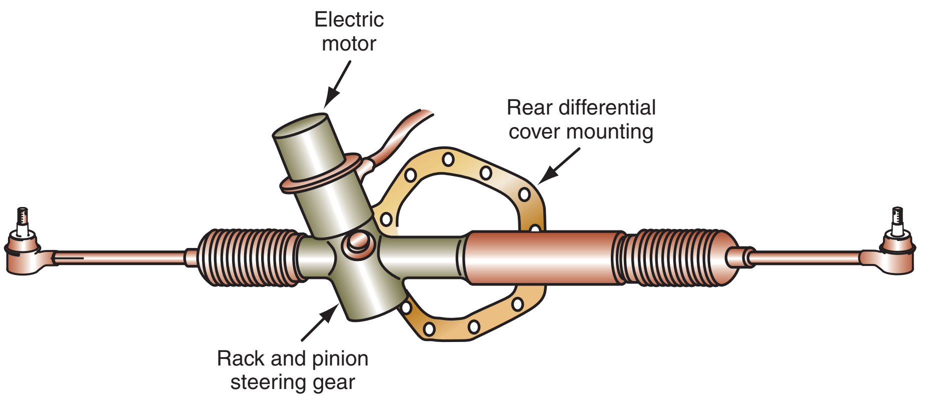

FIGURE 13-16 **Four-wheel steering gear and motor.**

Quadrasteer Four-Wheel Steering System Operation

The rear wheel steering module receives inputs from these sources:

1. Battery voltage
2. Ignition voltage
3. Class 2 serial data links
4. Steering wheel position sensor analog, marker pulse, and phase signals
5. Rear wheel position sensor signals
6. Vehicle speed sensor signal from the instrument panel cluster (IPC)
7. Rear wheel steering mode switch

In response to these input signals, the module commands the rear wheel steering motor to operate the rear wheel steering gear and provide the proper rear wheel steering angle.

In the 2-wheel steer mode the rear wheels are held in a centered position, and the rear wheel steering is disabled.

Neutral phase steering occurs when the rear wheels are centered in the straight-ahead position.

In the 4-wheel steer mode the rear wheel steering can provide negative phase steering, **neutral phase steering,** or **positive phase steering.** In the negative phase the rear wheels are steered in the opposite direction to the front wheels, and this phase occurs at low vehicle speeds. When the rear wheels are steered in the opposite direction to the front wheels, the vehicle turning radius is reduced and parking maneuverability is improved (Figure 13-17). In the neutral phase the rear wheels remain centered. If an electronic defect occurs in the rear wheel steering system, the rear wheels remain in the neutral phase. When the rear wheel steering control module commands positive phase steering, the module drives the electric motor and steers the rear wheels in the same direction as the front wheels. This

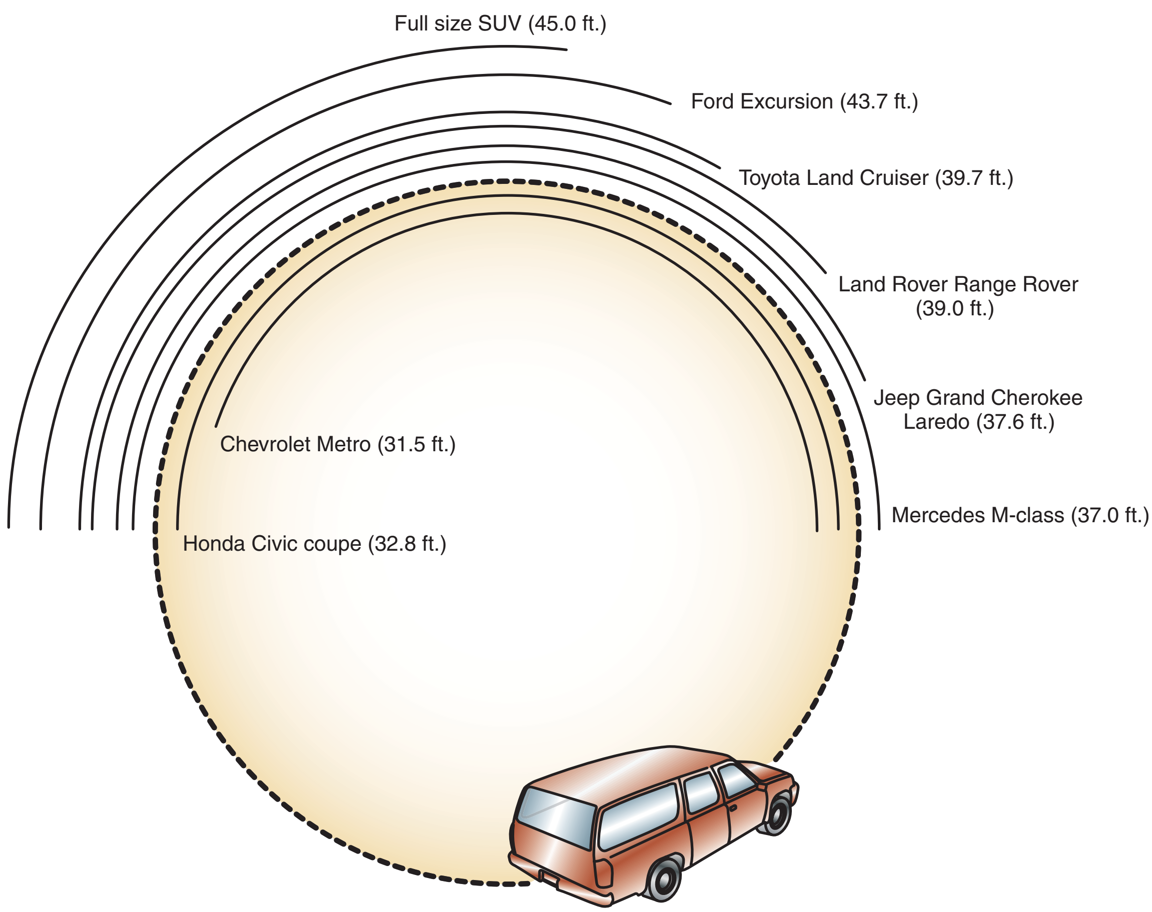

FIGURE 13-17 **Turning circle diameter, four-wheel steering system.**

action reduces **yaw forces** on the rear of the vehicle and improves steering control at higher speeds. The transition from negative phase to positive phase steering occurs at 40 mph (65 km/h).

Yaw forces tend to cause the rear of the vehicle to swerve sideways.

In the 4-wheel steer tow mode, the degrees of positive phase steering is increased compared to the 4-wheel steer mode, and the transition speed from negative phase steering to positive phase steering occurs at 25 mph (40 km/h). Below this speed the negative phase steering is similar to the negative phase steering in the 4-wheel steer mode.

WARNING: When diagnosing, servicing, or adjusting a 4WS system, it is very important to follow the diagnostic, service, and adjustment procedures in the vehicle manufacturer's service manual. Failure to follow these procedures may cause improper rear wheel steering operation and reduced vehicle stability that could result in a vehicle collision.

General Motors engineers decided to install the Quadrasteer system on an SUV because of the advantages of this system when hauling a trailer. When the rear vehicle wheels are steered in the opposite direction to the front wheels during low-speed turning, the trailer follows the true vehicle path more closely than it does with a two-wheel steering system. When backing up a trailer, steering the rear wheels in the opposite direction to the front wheels provides better trailer response to vehicle steering inputs, and this action makes it easier to back the trailer into the desired position. When steering the vehicle at higher speeds such as lane changing, the positive steering action of the rear wheels reduces the articulation angle between the tow vehicle and the trailer. This action reduces the lateral forces applied to the rear of the tow vehicle by the trailer, which in turn reduces yaw velocity gain and improves trailer stability. On a full-size SUV, the Quadrasteer system reduces turning circle diameter from 45 ft. to 33.9 ft. (Figure 13-17).

AUTHOR'S NOTE: Previous to 2002, four-wheel steering was available on a few imported cars; however, these systems were never sold in large numbers. The Quadrasteer system is the first four-wheel steering system to be offered on an SUV and marketed on the basis of improved steering control when trailer hauling. The question resulting from this application of four-wheel steering systems is: Will these systems be widely accepted by the motoring public or will they be considered too expensive for the advantages they provide?

As an automotive technician, you must keep up-to-date on the changes in automotive electronics, and these changes are occurring at a very rapid pace. It has been my experience that one of the best ways to keep up-to-date is to join professional technician's organizations such as the Service Technicians Society (STS), or the International Automotive Technicians' Network (IATN). As a member of these organizations, you will be able to obtain information on the latest automotive electronics technology and the solutions to diagnostic problems related to automotive electronics.

REAR ACTIVE STEERING SYSTEM

Rear active steering (RAS) has recently been introduced as standard equipment on the 2006 Infinity M series luxury car. The manufacturer claims this car is the most technologically advanced Infinity model ever developed, and also claims the RAS is probably the most significant new technology on the vehicle. This technology is new to the luxury car segment. The RAS makes the steering and handling characteristics on this long-wheelbase car more nimble and agile compared to models without this technology.

The RAS improves steering and handling by adjusting the geometry of the rear suspension in relation to steering input and vehicle speed. The RAS control unit calculates the ultimate vehicle dynamics from the input signals from a group of sensors. In response to these inputs the control unit operates the electric actuator to lengthen or shorten each lower rear suspension link (Figure 13-18). This action provides a possible 1° turn on each rear wheel.

When the vehicle begins turning a corner, driving around a curve, or making a lane change at midspeed, the control unit operates the RAS actuator to initially turn the rear wheels in the negative phase mode in relation to the front wheels (Figure 13-19). This action provides improved turn-in response.

When the steering wheel rotation indicates the vehicle is exiting a corner or making a lane change at mid-speed, the control unit operates the RAS actuator to turn the rear wheels in the positive phase mode in relation to the front wheels (Figure 13-20). Under this condition yaw forces are reduced on the rear of the vehicle to provide improved vehicle stability.

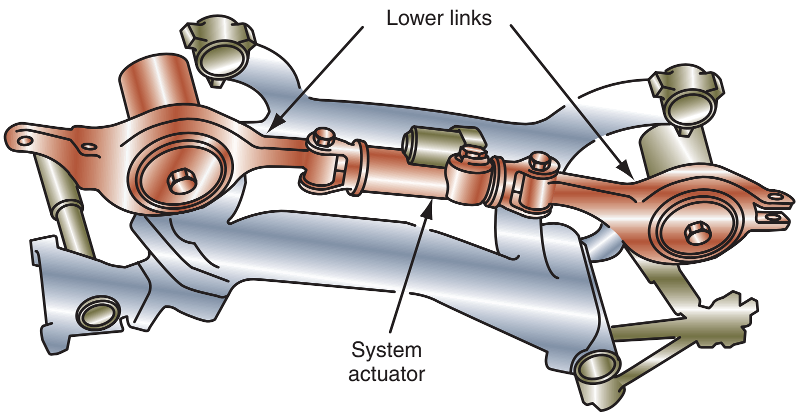

FIGURE 13-18 **Rear steering actuator and adjustable lower links.**

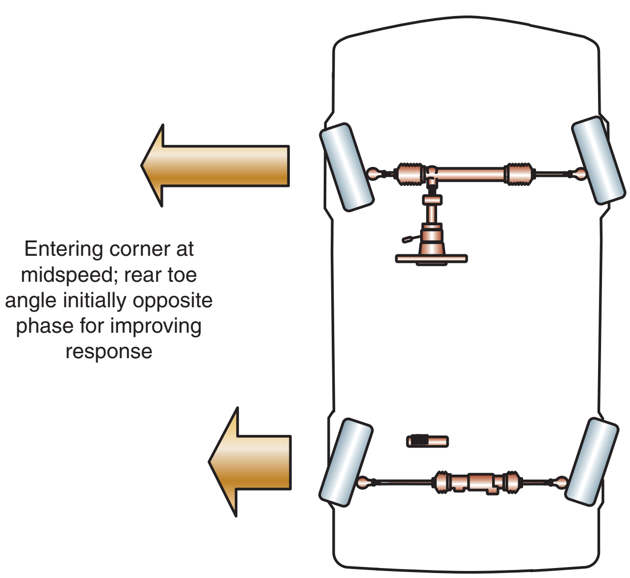

FIGURE 13-19 **Rear wheel steering during negative phase operation.**

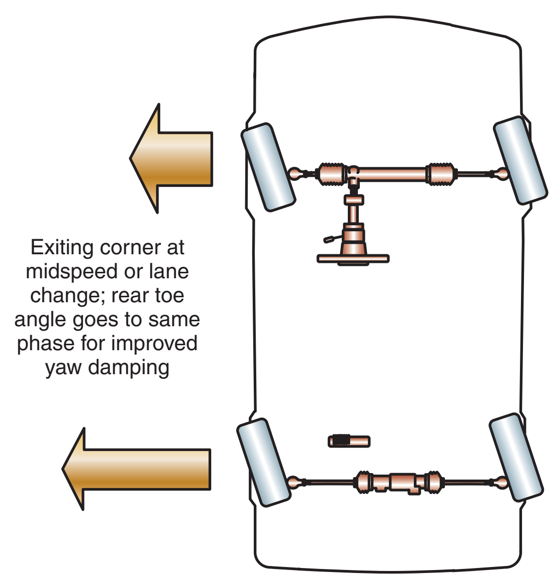

FIGURE 13-20 **Rear wheel steering during positive phase operation.**

Four-Wheel Active Steering (4WAS)

4WAS System Design

Some vehicles are equipped with **four-wheel active steering (4WAS)** to provide improved overall steering performance while simultaneously reducing steering effort. The 4WAS system is designed to provide fast steering responses in the low to medium speed range combined with vehicle stability at high speeds.

Four-wheel active steering (4WAS) may be defined as front and rear wheel steering in which a computer(s) can electronically change the front and rear steering angles.

The 4WAS has a front electronic control unit (ECU) and a main (rear) ECU. The 4WAS system has a front steering actuator mounted coaxially in the front steering shaft (Figure 13-21). The front actuator contains a front wheel steering angle sensor, a front lock solenoid valve, a front motor, and a gear shaft (Figure 13-22). The front ECU operates the motor and gear shaft in the front actuator to change the steering ratio. The lock solenoid valve in the front steering actuator locks this actuator so the steering ratio cannot change if a defect occurs in the system.

The rear steering actuator body is attached to a chassis member, and the outer ends of the actuator shaft are linked to the rear wheels. The rear steering actuator contains a rod attached to the rear steering arms (item 1), a motor (item 4), motor shaft and drive gear (item 5), a driven gear (item 7), a housing assembly (item 3), and a rear wheel steering angle sensor (item 6) (Figure 13-23).

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The main ECU is mounted in the trunk, and controls the rear steering actuator, and the front ECU is mounted under the dash and controls the front steering actuator. The software in the ECUs contains a reference model that contains the desired dynamic steering characteristics. The ECUs operate the front and rear steering actuators to conform to the reference model in the software.

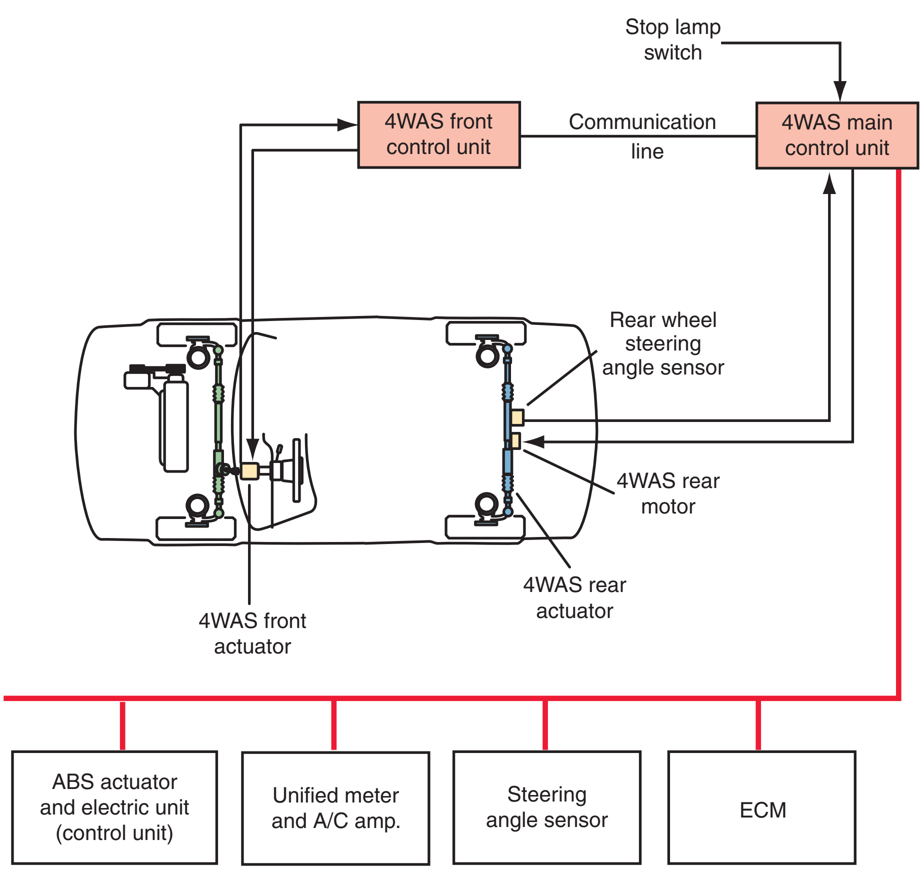


FIGURE 13-21 **4WAS system.**

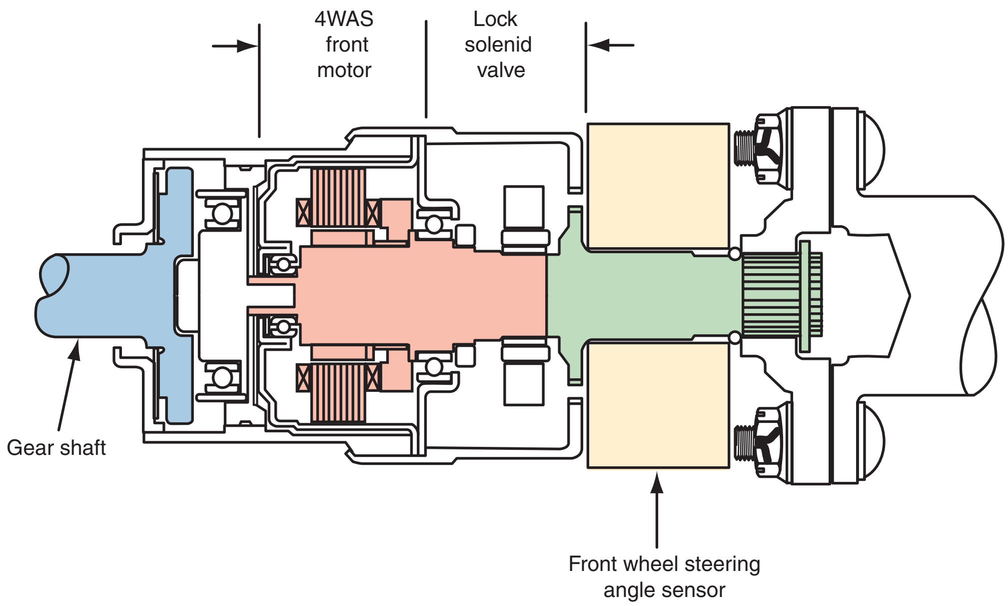


FIGURE 13-22 **4WAS front actuator.**

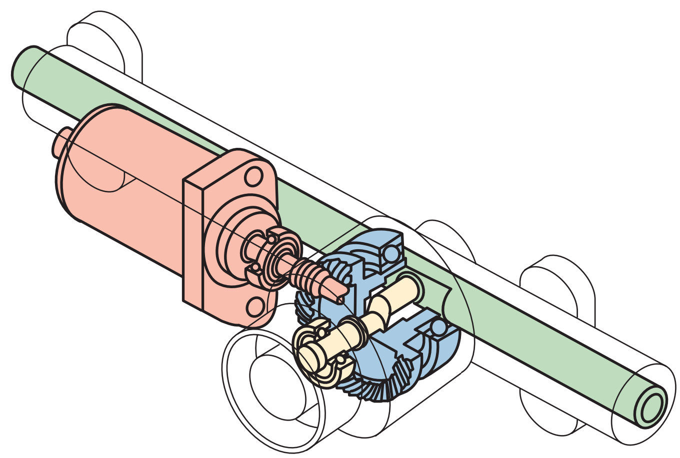


FIGURE 13-23 **4WAS rear actuator.**

The main control unit calculates the front and rear steering angles that will provide the best steering performance and vehicle stability based on the front and rear steering angle sensor inputs and the vehicle speed input. The vehicle speed input is sent from the antilock brake system (ABS) control unit through the CAN communication network to the main control unit. Engine speed signals are transmitted from the engine electronic control unit (ECU) via the CAN network to the main control unit. The 4WAS warning light is mounted in the unified meter in the instrument panel, and operated by the main control unit.

4WAS System Operation

When cornering at low speed the front control unit operates the front steering actuator to reduce the steering gear ratio. This action increases the front steering angle with less steering wheel movement and reduced driver steering effort (Figure 13-24).

When changing lanes in the medium-speed range, the front steering actuator can increase the front steering angle in relation to steering wheel rotation, and simultaneously the rear steering actuator steers the rear wheels a small amount in the same direction. When this action is taken, yaw motion, lateral force, and vehicle slide slip are reduced (Figure 13-25).

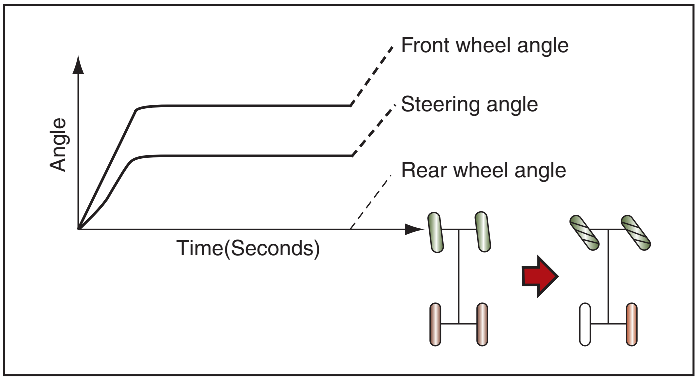


FIGURE 13-24 **Steering angles while cornering at low speed.**

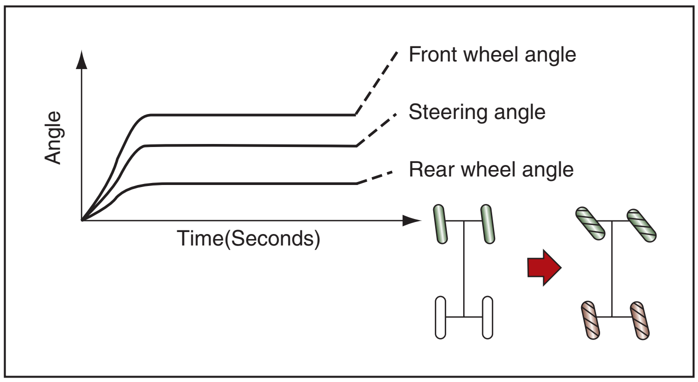


FIGURE 13-25 **Steering angles while changing lanes at medium speed.**

When changing lanes at high speed, the front steering actuator increases the front steering ratio so the driver steering effort is increased, steering wheel movement is also increased, and steering angle is decreased in relation to steering wheel rotation. This action provides more road feel to the driver. Simultaneously, the rear steering actuator steers the rear wheels a few degrees in the same direction (Figure 13-26). This action provides improved steering response and vehicle stability.

The 4WAS system has an electronic power steering (EPS) system. The 4WAS main control unit operates a solenoid valve in the EPS system (Figure 13-27). If this solenoid valve is open, some of the power steering pump pressure flows through the solenoid and returns through the steering gear passages to the power steering reservoir. Under this condition, power steering pump pressure is reduced. When the solenoid valve is closed, the solenoid blocks the flow of fluid through the valve, and this action increases power steering pump

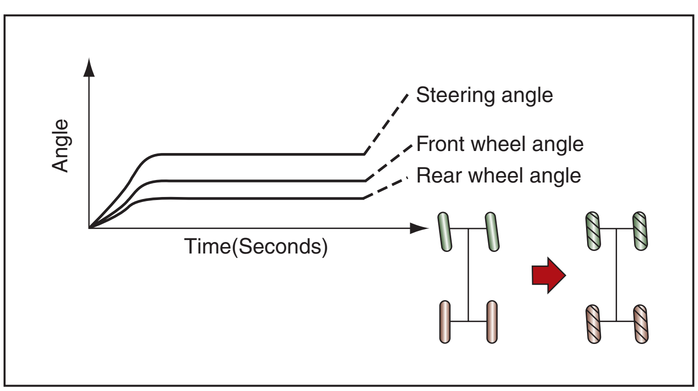


FIGURE 13-26 **Steering angles while changing lanes at high speed.**

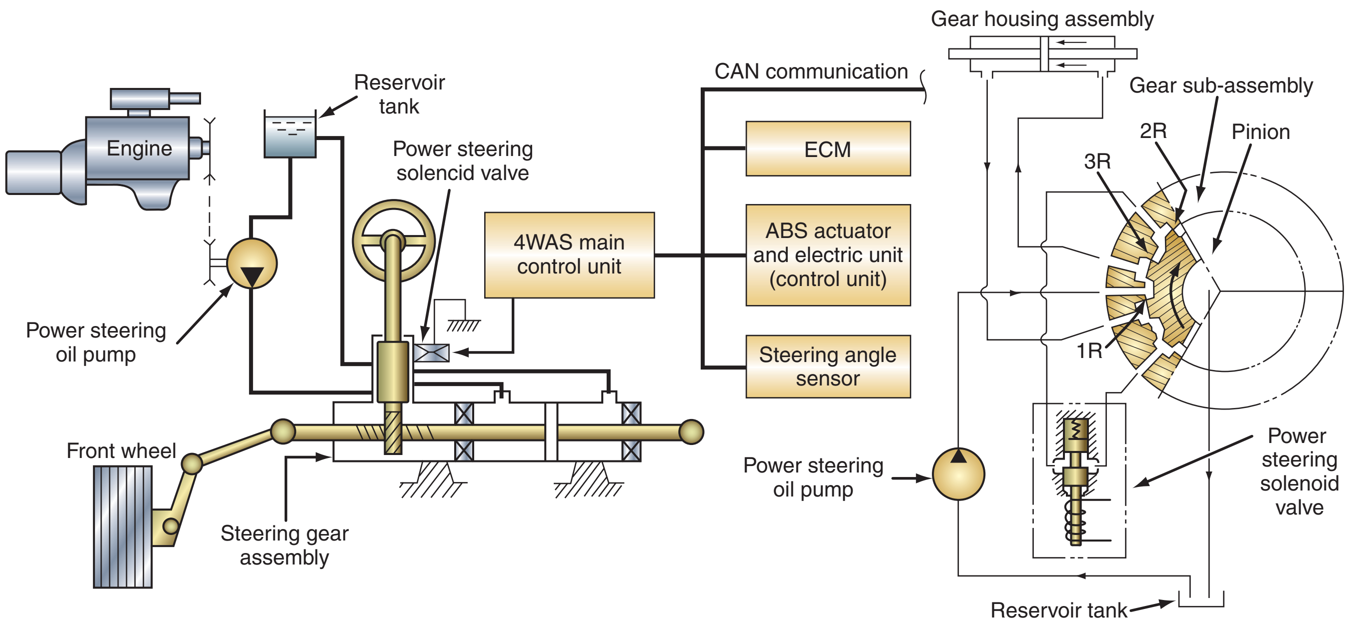


FIGURE 13-27 **4WAS EPS system.**

pressure. When the engine is idling or the vehicle is operating at low speeds, the main control unit energizes and closes the 4WAS solenoid valve. This action prevents the power steering pump pressure from flowing through the solenoid valve, and power steering pump pressure, and power steering assist are increased, resulting in a decrease in steering effort and reduced driver fatigue.

If the vehicle is driven at higher speeds, the 4WAS main control unit de-energizes the solenoid valve, allowing it to open. Under this condition, some of the power steering fluid pressure flows through the solenoid valve to the reservoir. This action decreases power steering pump pressure and increases steering effort for improved road feel.

Terms to Know

Analog voltage signal
Electronically controlled 4WS system
Four-wheel steering (4WS)
Four-wheel active steering (4WAS)
Neutral phase steering
Positive phase steering
Quadrasteer
Rear active steering (RAS)
Rear steering actuator
Sideslip
Steering angle

Summary

- The rear wheel steering system in a four-wheel steering system is usually electronically controlled.
- Steering the rear wheels in the opposite direction to the front wheels at low speed provides a shorter turning circle, or radius, for easier maneuvering.
- Steering the rear wheels in the same direction as the front wheels at higher speeds reduces rear sideslip and improves vehicle stability while cornering or changing lanes.
- In an electronically controlled 4WS system, there is no mechanical connection between the front steering gear and the rear steering gear.
- In an electronically controlled 4WS system, the rear steering actuator contains an electric motor that is controlled by the 4WS control unit in response to various input sensor signals.
- In a Quadrasteer system, the control unit uses inputs from the vehicle speed sensor (VSS) and the front steering position sensor to control the rear steering actuator.
- A higher output alternator is required on a Quadrasteer system because of the higher current draw of the rear actuator.
- Negative phase steering occurs at lower speeds when the rear wheels are steered in the opposite direction as the front wheels.

Summary

- Positive phase steering occurs at higher speeds when the rear wheels are steered in the same direction as the front wheels.
- Steering the rear wheels in the same direction as the front wheels at higher speeds reduces the lateral forces applied to the rear of a vehicle, and this action reduces yaw velocity.
- When towing a trailer, steering the rear wheels in the same direction as the front wheels at higher speeds improves trailer stability.

Terms to Know (continued)

Steering wheel angle sensor
Transistor
Turning circle
Yaw forces

Review Questions

Short Answer Essays

1. Explain the advantage of a 4WS system while parking a vehicle.
2. Explain the advantage of a 4WS system while the vehicle is operating at higher speed.
3. Describe why the opposite phase rear wheel steering angle must be limited to 5° or 6°.
4. Describe how the rear steering gear is driven in an electronically controlled 4WS system.
5. Describe the design and purpose of the main rear wheel angle sensor in an electronically controlled 4WS system.
6. Describe the design and purpose of the sub rear wheel angle sensor in an electronically controlled 4WS system.
7. Explain the advantages of a Quadrasteer system when towing a trailer.
8. Explain the purpose of the front main steering wheel angle sensor in an electronically controlled 4WS system.
9. Explain the advantages of a Quadrasteer system when backing up a trailer.
10. Describe the effect of a 4WS system on turning circle diameter.

Fill-in-the-Blanks

1. When a vehicle with 4WS is parked near the curb, the rear wheels may strike the ______________ while driving out of the parking space.
2. In an electronically controlled 4WS system, the electronic module receives input signals from these sensors: ______________ ______________ ______________ ______________ ______________ ______________
3. In an electronically controlled 4WS system, the electronic module operates a(n) ______________ ______________ to steer the rear wheels.
4. In an electronically controlled 4WS system, the direction sensor in the front main steering angle sensor contains a(n) ______________ ______________.
5. The front main steering angle sensor in an electronically controlled 4WS system is mounted in the ______________ ______________.
6. The main rear steering angle sensor in an electronically controlled 4WS system contains a rotating ______________ ______________.
7. During negative phase steering, the rear wheels are steered in the ______________ ______________ to the front wheels.
8. When towing a trailer and changing lanes at higher speeds, the Quadrasteer system reduces ______________ ______________ on the rear of the vehicle.
9. A 4WS switch on the dash allows the driver to select ______________ ______________ ______________ or ______________ ______________ ______________.
10. In a Quadrasteer system, the rear steering arms are integral with the spindles, and these arms face ______________.

Multiple Choice

1. When a typical Quadrasteer system is operating in the 4-wheel steer mode, the rear wheels are steered in the opposite direction to the front wheels if the vehicle is operating at:
   A. 30 mph (48 km/h).
   B. 45 mph (72 km/h).
   C. 55 mph (88 km/h).
   D. 65 mph (104 km/h).

2. All of these statements about a 4WS system are true EXCEPT:
   A. A 4WS system reduces yaw forces on the vehicle at higher speeds.
   B. A 4WS system provides a smaller turning circle.
   C. A 4WS system reduces tire wear.
   D. A 4WS system improves vehicle maneuverability at low speeds.

3. When a Quadrasteer system is switched from the 4WS mode to the 4WS tow mode, the positive steering angle:
   A. Decreases.
   B. Remains the same.
   C. Increases.
   D. Is reversed.

4. If an electrical defect occurs in a 4WS system the:
   A. The rear wheels remain in the centered position.
   B. Positive phase rear wheel steering is cancelled.
   C. Negative phase rear wheel steering is increased.
   D. Positive phase rear wheel steering angle is increased, and negative phase rear wheel steering is decreased.

5. In a typical Quadrasteer system the rear wheel bearings:
   A. Must be repacked with grease every 60,000 mi. (96,000 km/h).
   B. Must be adjusted each time they are serviced.
   C. Are nonserviceable and must be replaced as a unit.
   D. Must be serviced when the rear axle joints are replaced.

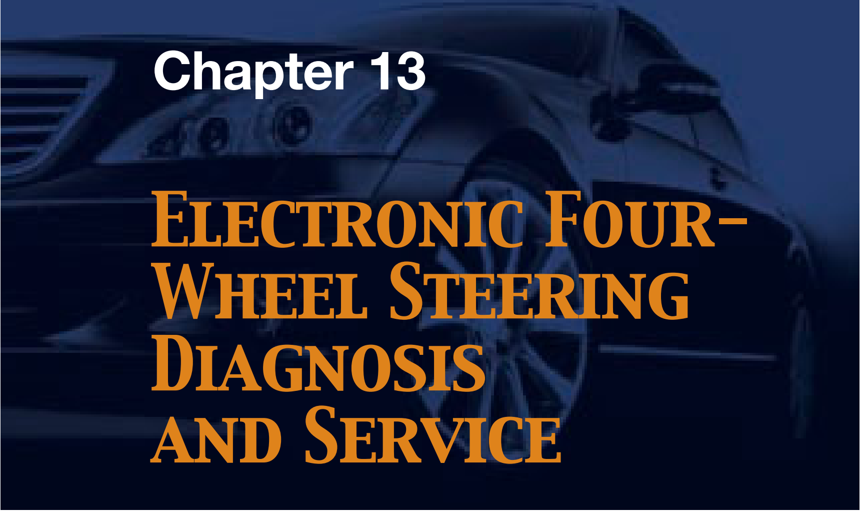
6. In an electronically controlled 4WS system:
   A. The rear steering gear pinion is driven by an electric motor.
   B. There is a mechanical connection between the front steering gear and the rear steering actuator.
   C. The rear wheel speed sensor voltage frequency is constant regardless of wheel speed.
   D. The voltage signal from the vehicle speed sensor is only used by the 4WS control unit.

7. All of these statements about electronically controlled 4WS systems are true EXCEPT:
   A. The rear wheel steering angle is greater in the opposite phase compared to the same phase.
   B. The rear wheel steering angle decreases when the vehicle speed is increased from 0 mph to 18 mph (29 km/h).
   C. When the rear wheels are steered, voltage is sent directly to the armature in the rear steering actuator.
   D. When the ignition switch is turned off, a spring in the rear steering actuator centers the rear wheels.

8. In a Quadrasteer system, the rear steering actuator is operated by:
   A. Linkage to the front steering gear.
   B. An electric motor.
   C. Hydraulic pressure from the power steering system.
   D. Transmission fluid pressure.

9. All of these statements about a 4WAS system are true EXCEPT:
   A. The front steering actuator is mounted in the front steering gear.
   B. The rear steering actuator body is attached to the chassis.
   C. The rear ECU controls only the rear actuator.
   D. During a lane change of 60 mph (96 kph), the 4WAS reduces yaw motion.

10. In an electronically controlled 4WS system the control module uses all of these inputs EXCEPT:
    A. Steering wheel rotational speed.
    B. Vehicle speed.
    C. Front steering angle.
    D. Brake pedal movement.



Chapter 13

Electronic Four-Wheel Steering Diagnosis and Service

Upon completion and review of this chapter, you should be able to:

- Perform a preliminary inspection on a four-wheel steering (4WS) system.
- Perform a trouble code diagnosis on a 4WS system with the ignition switch on.
- Perform a trouble code diagnosis on a 4WS system with the engine running.
- Remove and replace the rear steering actuator.
- Remove and replace the tie-rod ends on the rear steering actuator.
- Remove and replace tie-rods and boots on the rear steering actuator.
- Remove and replace the rear main steering angle sensor.
- Remove and replace the rear sub steering angle sensor.
- Diagnose four-wheel active steering systems (4WAS).

BASIC TOOLS

Basic technician's tool set
Service manual
Jumper wire
Floor jack
Safety stands
Wax marker
Silicone grease
Chassis lubricant
Cotter pins
Length of stiff wire

Diagnosis, service, and adjustments on 4WS systems must be performed precisely as explained in the vehicle manufacturer's service manual. On some systems inaccurate sensor adjustments may cause improper rear wheel steering operation, and this may result in reduced steering control. Always follow the diagnostic, service, and adjustment procedures carefully and accurately!

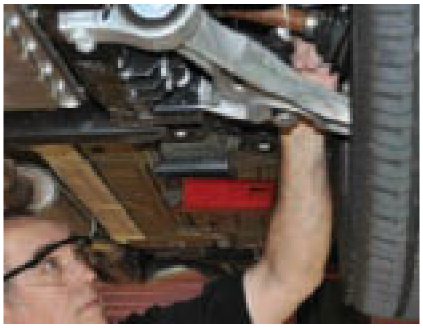
Preliminary Inspection

Prior to any four-wheel steering diagnosis, the following concerns should be considered:

1. Have any suspension modifications been made that would affect steering?
2. Are the tire sizes the same as specified by the vehicle manufacturer?
3. Are the tires inflated to the pressure specified by the vehicle manufacturer?
4. Is the power steering belt adjusted to the vehicle manufacturer's specified tension?
5. Is the power steering pump reservoir filled to the proper level with the type of fluid specified by the vehicle manufacturer?
6. Is the engine idling at the speed specified by the vehicle manufacturer? Is the idle speed steady?
7. Is the steering wheel original equipment?
8. Is the battery fully charged?
9. Are all electrical connections clean and tight?
10. Is there any damaged electrical wiring in the system?
11. Are the rear wheel steering fuses in satisfactory condition?
12. Are there any damaged or worn rear steering gear or rear axle components?
13. Is the Service 4 Wheel Steer indicator illuminated in the instrument panel cluster?

Photo Sequence 23 illustrates a preliminary four-wheel steering inspection.

Preliminary Inspection, Four-Wheel Steering Diagnosis



P23-1 **Inspect the front and rear suspension and steering for modifications and damage that could affect steering.**

P23-2 **Check the tire sizes to be sure they are the size specified by the vehicle manufacturer.**

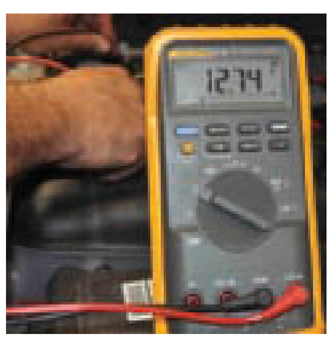
P23-3 **Inflate the tires to the specified pressure.**

P23-4 **Check the power steering belt tension.**

P23-5 **Check the fluid level in the power steering pump reservoir.**

P23-6 **Be sure the engine idle speed is correct.**

P23-7 **Be sure the steering wheel is original equipment.**

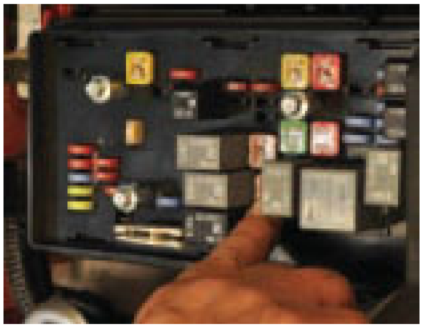


P23-8 **Be sure the battery is fully charged.**

P23-9 **Inspect all electrical connections and harness in the four-wheel steering system to be sure they are in satisfactory condition.**

PHOTO SEQUENCE 23 (CONTINUED)

PRELIMINARY INSPECTION, FOUR-WHEEL STEERING DIAGNOSIS



P23-10 **Check the rear wheel steering system fuses.**

P23-11 **Check the four-wheel steering warning light in the instrument panel for proper operation.**

A fail-safe mode may be called a backup mode.

The Society of Automotive Engineers (SAE) J1930 terminology is an attempt to standardize electronics terminology in the automotive industry.

In the SAE J1930 terminology, the term malfunction indicator light (MIL) replaces other terms for computer system indicator lights.

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QUADRASTEER DIAGNOSIS

Fast, accurate Quadrasteer diagnosis is very important when correcting steering complaints. If the preliminary inspection does not indicate any problems, the next step in Quadrasteer diagnosis is to perform a diagnostic system check using these steps:

1. With the ignition switch off, connect a scan tool to the DLC under the dash.
2. Turn on the ignition switch, and select Rear Wheel Steering Control Module on the scan tool. If the scan tool does not communicate with this module, check the scan tool electrical connection and the data links. Be sure the scan tool communicates with all the other modules on the vehicle.
3. Access the Class 2 Power Mode on the scan tool, and rotate the ignition switch through all positions while observing the scan tool. The engine may start with the ignition switch in the Start position. The ignition switch position displayed on the scan tool should match the actual ignition switch position.
4. Select the Display DTCs function on the scan tool and then select Rear Wheel Steering Control Module to display the DTCs related to the 4WS system. Select all the other modules on the vehicle, and display any DTCs stored in these modules. Record all DTCs.
5. Are there any DTCs beginning with a U? These DTCs relate to data link problems and must be repaired before proceeding with 4WS diagnosis.
6. Does the scan tool display DTC B1000? This DTC indicates an internal defect in the body control module (BCM), and causes the BCM to refuse all additional inputs. The Quadrasteer system depends on some inputs from the BCM. Therefore, 4WS operation is affected by this BCM problem.

Rear Wheel Steering Data Display

Select Rear Wheel Steering and Data Display on the scan tool. Observe the data displayed on the scan tool and illustrated in Figures 13-1 and 13-2. Compare the displayed data to the vehicle manufacturer's specified data. Repair the cause of any incorrect data.

Compare the incorrect data to the DTCs recorded previously. If any DTCs and incorrect data are from the same component, repair this component or the related circuit.

Rear Wheel Steering DTC Interpretation

The possible 4WS system DTCs and causes are the following:

1. B3593 – The mode select switch 5 V reference circuit is open, shorted to ground, or shorted to voltage.
2. C0000 – The vehicle speed sensor, related circuit, or Class 2 data links are defective.

Operating conditions: Ignition ON/Engine ON

Scan tool parameter	Data List	Units displayed	Typical data value
2 wheel steer mode lamp	Output	On/Off	Varies
4 wheel steer mode lamp	Output	On/Off	Varies
4WS-Tow mode lamp	Output	On/Off	Varies
8-digit GM part number	ID information	Numerical	Varies
Actual rear wheel steering angle	Data display	Degrees	0˚ to 12˚
Base model part number	ID information	Numerical	Varies
Battery voltage	Data display	Voltage	9.0-16.0 volts
Calibration part number	ID information	Numerical	Varies
Calibration S/W suffix	ID information	Numerical	Varies
Digital SWPS phase A	Data display	High/Low	Varies
Digital SWPS phase B	Data display	High/Low	Varies
Hall sensor reference	Data display	Voltage	12 volts
Ignition 3	Data display	Voltage	9.0-16.0 volts

FIGURE 13-1 **Rear wheel steering data.**

Operating conditions: Ignition ON/Engine ON

Scan tool parameter	Data List	Units displayed	Typical data value
Ign. cycles since last fault	Data display	Counts	Counts
Marker pulse	Data display	High/Low	1
Motor current	Data display	Amps	20-50A typical 0 to 85A max.
Motor relay commanded state	Data display	On/Off	Varies
Motor relay feedback state	Data display	On/Offg	Varies
Rear steer mode actual	Data display	2WS,4WS,4WS tow	Varies
Rear steer mode requested	Data display	2WS,4WS,4WS tow	Varies
Rear steer position 1	Data display	Voltage	.25 to 4.75 volts
Rear steer position 2	Data display	Voltage	.25 to 4.75 volts
Rear steer select switch	Data display	On/Off	Off
Rear wheel centering 1	Data display	Voltage	2.5 volts
Rear wheel centering 2	Data display	Voltage	2.5 volts
Requested rear steer angle	Data display	Degrees	0˚ to 12˚
Sensor supply voltage	Data display	Voltage	4.97 volts
Steering wheel angle	Data display	Degrees	-609˚ to +609˚
Steering wheel angle (TBC)	Data display	Degrees	.25 to 4.75 volts
Steering wheel sensor signal	BCM data	Voltage	Varies
Vehicle speed	Data display	km/h (mph)	

FIGURE 13-2 **Rear wheel steering data (continued).**

3. C0253 – The steering wheel position sensor phase A and phase B voltage signals may be out of the valid alignment range, or the steering wheel position marker pulse points may not be occurring at the proper time in relation to steering wheel rotation (Figure 13-3). The steering wheel position sensor analog voltage may be out of the valid alignment range (Figure 13-4), the rear wheel position sensor analog voltage may be out of the valid alignment range, or a valid Learn Wheel Alignment Procedure may not have been performed.
4. C0455 – The steering wheel position sensor phase A, phase B, or marker pulse signals are defective or the related circuits are open, or shorted to ground or voltage. This DTC may also be caused by a fault that sets a BCM DTC C0472 or C0473.
5. C0472 or C0473 – The BCM detects the analog steering wheel position sensor circuit is open or shorted to ground or voltage.
6. C0522 – The rear wheel position sensor position 1 or position 2 signals are defective, the 5 V reference circuit to this sensor is open or shorted, or the sensor ground circuit is open.
7. C0527 – The Hall Effect switches in the rear steering gear actuator motor are defective, the voltage supply to these switches is open, or the ground circuit is open.
8. C0532 – The rear wheel position sensor and the actual rear wheel position varies by more than 1.4°.
9. C0533 – The shorting relay in the rear steering actuator motor is stuck open or closed.
10. C0538 – The rear steering motor electrical circuit is open, or shorted to ground or voltage.
11. C0543 – The difference between the commanded rear wheel steering position and the actual rear wheel steering position exceeds 3°.
12. C0550 – When the ignition switch is turned on, the rear wheel steering control module detects an internal malfunction.

SERVICE TIP:
If any of the sensors or the control module is replaced in a Quadrasteer system, a Learn Rear Wheel Alignment Procedure must be performed with a scan tool.

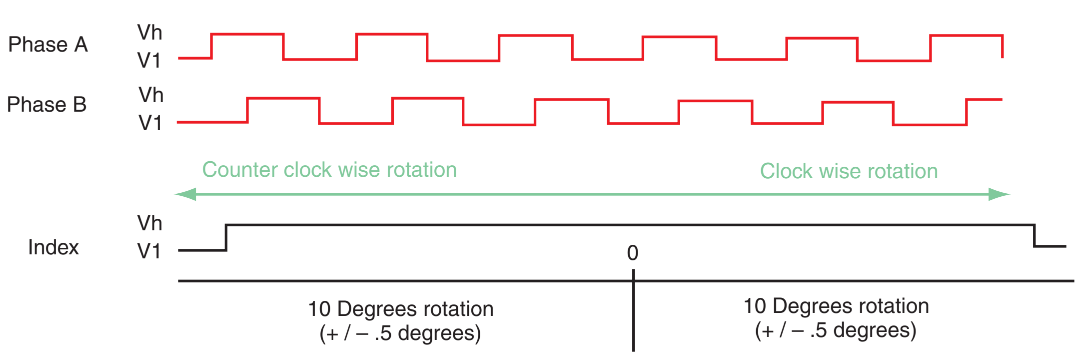

FIGURE 13-3 **Steering wheel position sensor phase A, phase B, and marker pulse signals.**

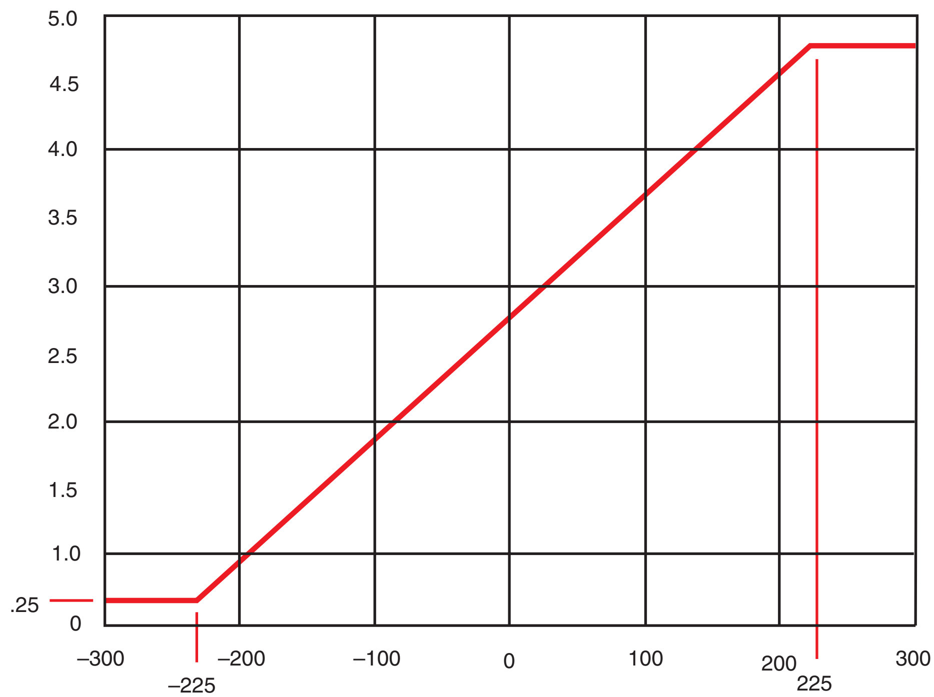

FIGURE 13-4 **Steering wheel position sensor analog voltage.**

SERVICE TIP:
If step 6 is not completed properly, a false steering wheel position sensor DTC may be set in the rear wheel steering control module memory.

The vehicle manufacturer's service manual contains detailed diagnostic procedures for each rear wheel steering DTC. These procedures must be followed when diagnosing the cause of any DTC. Table 13-1 provides a general Quadrasteer diagnostic procedure.

Rear Wheel Steering Learn Rear Wheel Alignment Procedure

Follow these steps to complete a Learn Rear Wheel Alignment procedure:

1. Turn on the ignition switch and start the engine.
2. Connect the scan tool to the DLC under the dash.
3. Center the steering wheel.
4. Lift the rear of the vehicle so the rear tires are a few inches off the shop floor. Be sure the chassis is securely supported on safety stands, and the rear wheels are centered.
5. Select the Learn Alignment menu on the scan tool.

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TABLE 13-1 **QUADRASTEER DIAGNOSIS**

Problem	Symptoms	Possible Causes
Inoperative rear wheel steer system	Rear wheels do not steer when front wheels are turned	Open fuse(s) related to 4WS system Defect in data links Defective BCM Defective input sensor(s) Defective rear wheel steering gear
Repeated blowing of fuse(s) related to 4WS system	Inoperative rear wheel steering system	Grounded or shorted circuit in related fuse circuit
Improper 4WS operation	Steering wheel position sensor phase A, phase B, marker pulse, and steering wheel position analog voltage signals are out of alignment with steering wheel rotation; DTC C0253 displayed	Defective steering wheel position sensor Learn Rear Wheel Alignment procedure not performed after component replacement

6. Follow the directions on the scan tool. When directed, the front wheels must be turned 90° to the left and 90° to the right, and then returned to the center position.
7. Press the Continue button on the scan tool until the alignment procedure is completed.
8. Use the scan tool to erase the rear wheel steering DTCs.
9. Shut off the ignition, disconnect the scan tool, and lower the rear wheels onto the shop floor.

Electronically Controlled Four-Wheel Steering Diagnosis

If the four-wheel steering (4WS) control unit senses a failure in the system, the control unit switches to a **fail-safe mode**. In this mode, the control unit stores a trouble code or codes and illuminates the 4WS indicator light to inform the driver that a problem exists in the system. When this mode is entered, the 4WS control unit shuts off voltage to the rear steering unit and the rear wheels remain in the straight-ahead position.

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Damper Control

When the 4WS control unit enters the fail-safe mode, a quick return of the rear wheels to the straight-ahead position would adversely affect steering under certain steering wheel and rear wheel positions. To prevent this action, the 4WS control unit energizes the damper relay when it enters the fail-safe mode. The rear steering actuator motor is spun by the steering shaft movement as this shaft is moved to the centered position by centering spring force. This action causes the motor armature to act as a voltage generator. The voltage generated by the armature is fed back through the damper relay to the motor armature. Under this condition, the motor rotation is slowed and the return spring slowly moves the rear steering shaft to the straight-ahead position. Without the action of the damper relay, the return spring would move the rear steering shaft quickly to the straight-ahead position.

CAUTION: When diagnosing a computer system, never connect or ground any terminals unless instructed to do so in the vehicle manufacturer's service manual. This action may damage electronic components.

Trouble Code Diagnosis

Road Test

CUSTOMER CARE: While discussing customers' automotive problems, always remain polite and never make statements that make customers feel uninformed about their vehicles.

The 4WS control unit stores a fault code and illuminates the 4WS indicator light if a defect occurs in the system, even if the defect is temporary. Always ask the customer about the conditions that caused the 4WS indicator light to come on, and duplicate this condition during a road test. If the 4WS light is not illuminated during the road test, the system is satisfactory electronically and does not require further electronic diagnosis. The troubleshooting procedures in the vehicle manufacturer's service manual assume that the problem is present at the time of diagnosis.

CAUTION: When diagnosing a computer system, never disconnect or connect any computer system component with the ignition switch on unless instructed to do so in the vehicle manufacturer's service manual. This action may damage the computer or system components.

Trouble Code Display with Ignition Switch On

Always follow the exact 4WS service and diagnostic procedures in the vehicle manufacturer's service manual. These procedures vary depending on the make and year of the vehicle.

The following are typical procedures for a Honda Prelude. These procedures should be avoided until after the diagnosis is complete because any of these procedures will erase trouble codes:

1. Disconnect the battery terminals.
2. Disconnect the 4WS control unit connector.
3. Remove the number 43 clock-radio 10-A fuse from the underhood fuse/relay box.

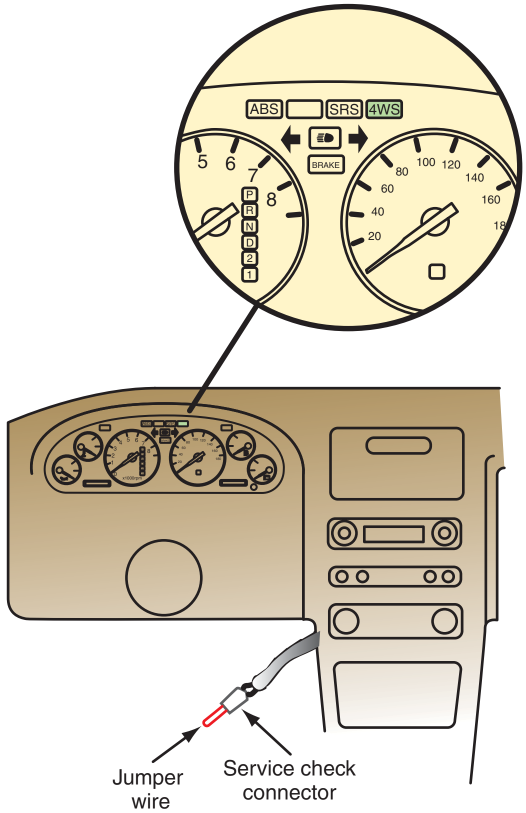

FIGURE 13-5 **Dual-terminal service check connector positioned behind the center console.**

CAUTION:
When performing electronic diagnosis on a vehicle equipped with an air bag, most vehicle manufacturers recommend turning the ignition switch off, disconnecting the negative battery cable, and waiting one minute before proceeding with electronic component diagnosis or service.

CAUTION:
When performing electronic diagnosis on a vehicle equipped with an air bag, follow all the service precautions recommended in the vehicle manufacturer's service manual. If these precautions are not followed, electronic components may be damaged.

When the two terminals on the **service check connector** are connected together, the 4WS computer supplies flash codes on the 4WS indicator light.

Follow these steps to obtain the trouble codes:

1. Remove the dual-terminal **service check connector** located behind the center console, and connect the two terminals in this connector with a jumper wire (Figure 13-5).
2. Turn on the ignition switch, but do not start the engine.
3. Observe the 4WS indicator light to read the trouble codes. Three longer flashes followed by a brief pause and one quicker flash indicates code 31. The codes are given in numerical order.
4. Record the fault codes.

Trouble Code Display with Engine Running

The 4WS control unit actually contains two processing units that are referred to as the main and sub processing units. Each processing unit can store a maximum of 10 trouble codes. If the trouble code diagnosis is performed with the engine running, the code display indicates whether the codes are stored in the main or sub processor.

When the service connector terminals are connected with a jumper wire and the engine is started, the 4WS indicator light follows this sequence if there are trouble codes in the main and sub processors:

1. Blinks quickly once when the ignition switch is turned on
2. Pauses for 3 seconds
3. Displays codes stored in the main processor
4. Pauses for 1.6 seconds
5. Blinks quickly for 3 seconds to indicate a separation between the main and sub processor codes
6. Pauses for 1.6 seconds
7. Displays codes stored in the sub processor
8. Pauses for 3 seconds, and then repeats the cycle (Figure 13-6)

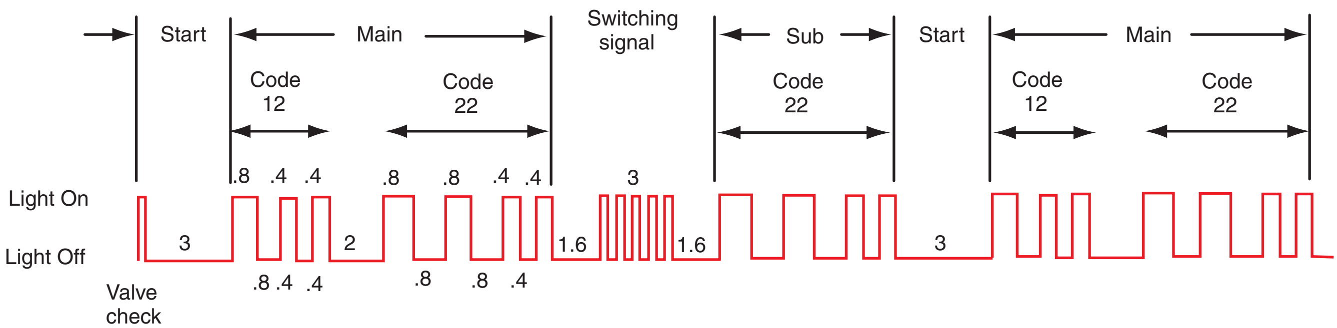

FIGURE 13-6 **Trouble codes in main and sub processors obtained with engine running.**

DTC	OPERATION	4WS INDICATOR LIGHT
70	The ignition is turned from Off to On while driving.	On
71	The car is driven aggressively with the driver and three passengers on board, or the steering wheel is turned with a rear wheel blocked by a curb, etc.	——
73	The engine is started while quick-charging the battery.	——
74	Driving the car with the parking brake On.	On 5 minutes after detection

FIGURE 13-7 **Codes that represent problems caused by abnormal or harsh driving conditions.**

Main Steering Angle Sensor Trouble Code

If a defect occurs in the main steering angle sensor system, the clock-radio 10-A fuse must be disconnected to cancel the 4WS indicator light. When defects occur in other parts of the electronic 4WS system, the 4WS indicator light is cancelled when the ignition switch is turned off. However, the 4WS indicator light is illuminated again when the ignition switch is turned on, and the 4WS control unit detects the problem again.

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Trouble Codes Representing Temporary Driving Conditions

Codes 70, 71, 73, and 74 represent problems resulting from abnormal or harsh driving conditions (Figure 13-7). When the 4WS control unit detects one of these problems, it does not illuminate the 4WS indicator light, but these codes are flashed during the diagnostic procedure.

CAUTION: Many steering service and diagnostic procedures require the installation of the rear steering center lock pin in the rear steering actuator to lock this unit in the centered position. If this lock pin is not installed, diagnosis will be inaccurate.

Rear Steering Actuator Service

Rear Steering Actuator Removal

WARNING: When turning the front wheels on a car with 4WS, keep your hands away from the rear steering mechanism and rear wheels to avoid hand injuries.

Follow these steps to remove the rear steering actuator:

1. Raise the vehicle on a hoist or lift the rear of the vehicle with a floor jack, and support the chassis with safety stands placed in the vehicle manufacturer's recommended locations.
2. Remove the cotter pin and nut from each tie-rod end.

CAUTION:
Do not start the engine with the rear steering center lock pin in place. This action may damage the lock pin and rear steering actuator.

SERVICE TIP:
Do not attempt to disassemble the rear steering actuator other than tie-rods, tie-rod ends, and sensors. This actuator is serviced as an assembly. Because individual parts for the actuator are not available, disassembly is a waste of time.

CAUTION:
Use the tie-rod end removal tool carefully to avoid damage to the tie-rod boot.

SPECIAL TOOLS
Tie-rod end removal tool

The **rear steering center lock pin** locks the rear steering in the centered position for test and service purposes.

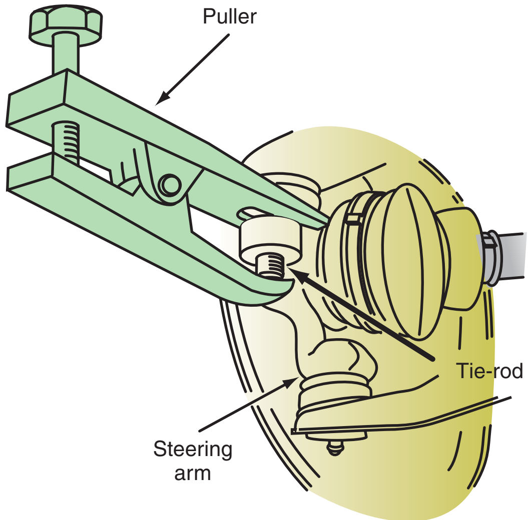


FIGURE 13-8 **Removing a tie-rod end with a special tool.**

3. Install a 12-millimeter (mm) nut on each tie-rod end until the nuts are flush with the tie-rod stud.
4. Install the special tool on the tie-rod end, and with the tool arms parallel, tighten the screw on the tool to loosen the tie-rod end (Figure 13-8). Repeat the procedure on both tie-rod ends.
5. Remove the nuts from the tie-rods and remove the tie-rods from the steering arms.
6. Remove the rear steering actuator cover (Figure 13-9).
7. Remove the cap bolt and washer and install the **rear steering center lock pin** (Figure 13-10).
8. Remove the ground cable connector and all wiring harness connectors on the rear steering actuator (Figure 13-11).
9. Remove the four mounting bolts and bracket, and remove the rear steering actuator (Figure 13-12).

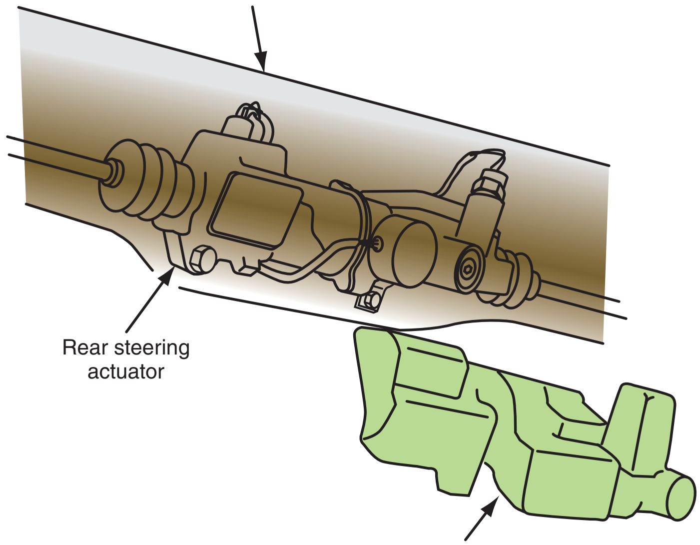


FIGURE 13-9 **Removing the rear steering actuator cover.**

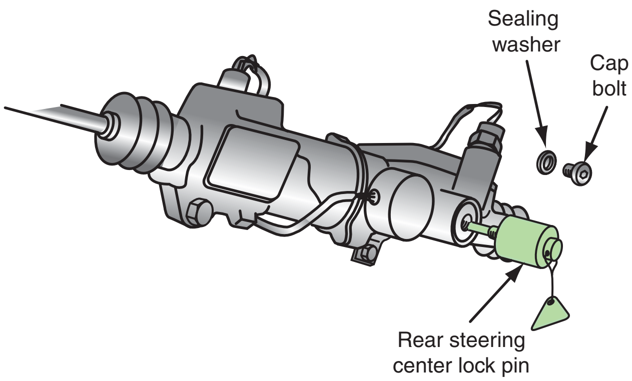


FIGURE 13-10 **Removing the cap bolt and washer, and installing the rear steering center lock pin.**

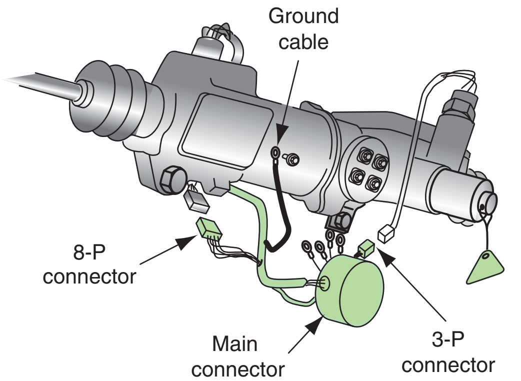


FIGURE 13-11 **Removing the ground cable connector and all wiring harness connectors on the rear steering actuator.**

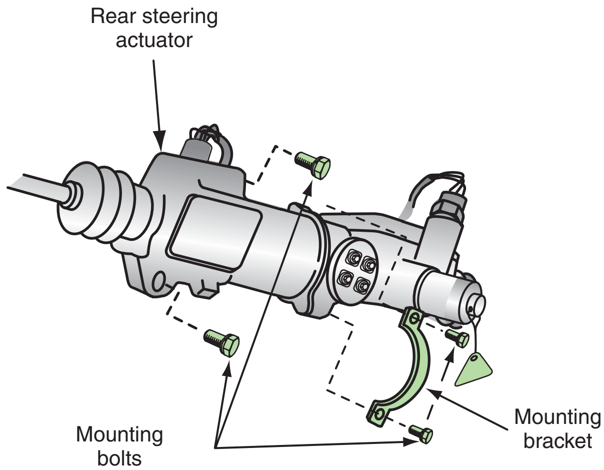


FIGURE 13-12 **Removing the four mounting bolts, bracket, and rear steering actuator.**

SPECIAL TOOLS

Rack holding tool

Tie-Rod and Tie-Rod End Removal

Follow these steps for tie-rod and tie-rod end removal:

1. Mark the relative position of the tie-rod end, locknut, and tie-rod with a wax marker.
2. Hold the tie-rod end with a wrench and loosen the locknut (Figure 13-13).
3. Remove the tie-rod end.
4. Remove the boot bands and clamps from the inner tie-rod ends (Figure 13-14).
5. Place the flat side of the rack holding tool toward the actuator housing and drive the special rack holding tool between the actuator housing and the stop washer with a soft hammer (Figure 13-15).
6. Straighten the tabs on the tie-rod lock washer.
7. Hold the shaft screw with the holding tool and loosen the tie-rod with a wrench (Figure 13-16).
8. Thread the tie-rod off the shaft screw and repeat this procedure on each tie-rod end.

SERVICE TIP:

Hold the special holding tool firmly while loosening the tie-rod to avoid applying rotational force to the shaft screw in the actuator.

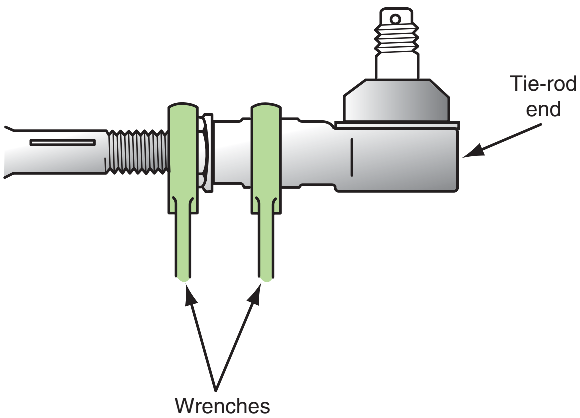


FIGURE 13-13 **Loosening the tie-rod end locknut.**

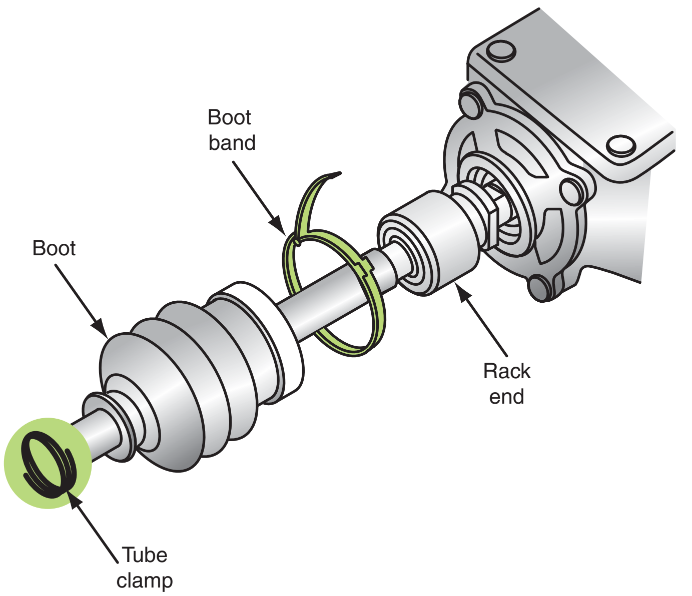


FIGURE 13-14 **Removing boot bands and clamps from the inner tie-rod end.**

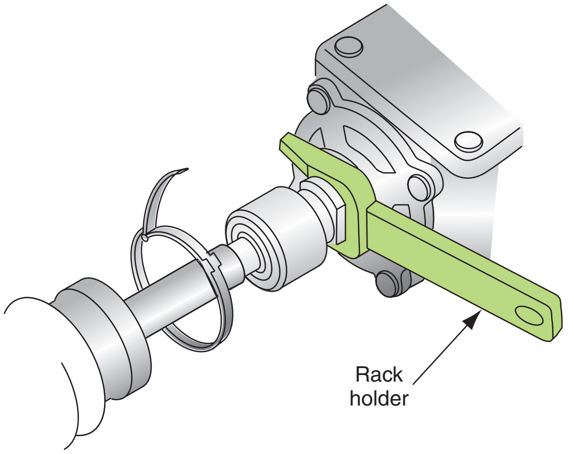


FIGURE 13-15 **Installing the special rack holding tool between the actuator housing and the stop washer.**

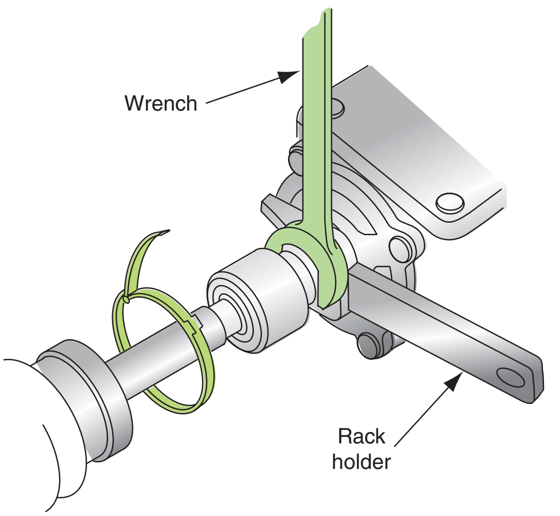


FIGURE 13-16 **Removing the tie-rod from the shaft screw.**

CAUTION:
Do not put grease on the boot installation shoulder and tapered section of the ball pin in the tie-rod end. Grease may cause these components to become loose.

Tie-Rod End Boot Removal and Replacement

Tie-rod end boots must be replaced if they are cracked, split, deteriorated, or loose.

Follow these steps to remove and replace the tie-rod end boots:

1. Use a large screwdriver to pry the old boot from the tie-rod end.
2. Pack the interior of the new boot with the vehicle manufacturer's recommended grease and place a light coating of grease on the boot lip.
3. Wipe the grease off the sliding surfaces of the ball pin with a shop towel; then pack the lower area around the ball pin and body with grease (Figure 13-17).
4. Use the special driving tool to install the new boot on the tie-rod end (Figure 13-18).
5. Wipe any grease from the tapered section of the ball pin with a shop towel. Apply sealant around the lower edge of the boot and tie-rod body.

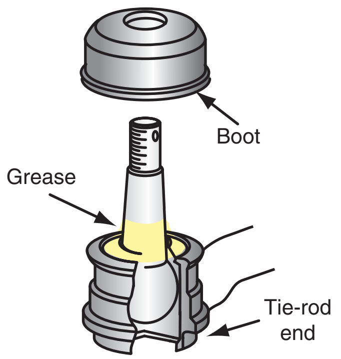


FIGURE 13-17 **Packing the boot and tie-rod end with grease.**

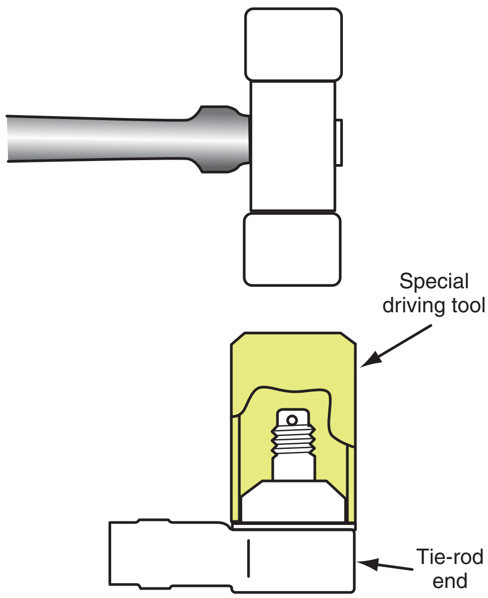


FIGURE 13-18 **Driving the boot onto the tie-rod end with a special driving tool.**

CAUTION:
Do not allow dust, dirt, or foreign material to enter the tie-rod end ball joint or boot because this contamination causes rapid component wear.

SPECIAL TOOLS
Tie-rod end removal tool

Installation of Tie-Rods and Tie-Rod Ends

Inner tie-rod boots must be replaced if they are cracked, split, deteriorated, or damaged.

Follow these steps for tie-rod and tie-rod end installation:

1. Install the tie-rod ends so the marks on the tie-rod ends, nuts, and tie-rods are aligned, and tighten the tie-rod nuts to the specified torque.
2. Screw each inner tie-rod onto the shaft screw while holding the lock washer so its tabs are in the inner tie-rod end. The stop washer must be installed on the shaft screw with the chamfered side facing outward (Figure 13-19).
3. Drive the special holding tool between the actuator housing and the stop washer with a soft hammer (Figure 13-20).
4. Hold the shaft screw with the holding tool and tighten the inner tie-rod end to the specified torque.

CAUTION:
Never apply axial impact or rotational force to the shaft screw in the rear steering actuator. Either of these actions may cause internal actuator damage.

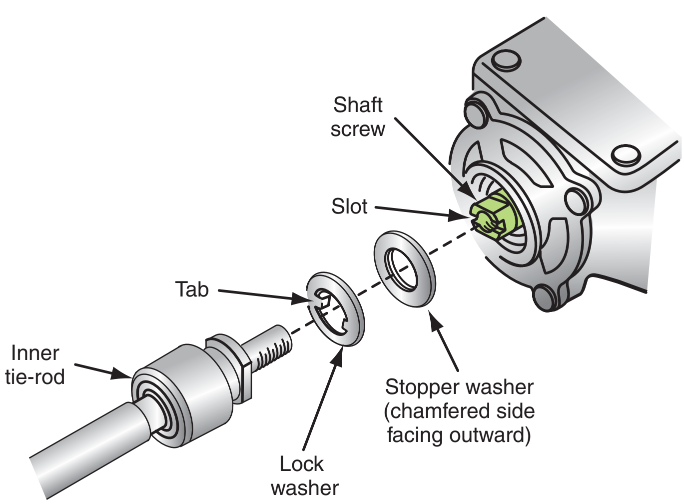


FIGURE 13-19 **Installing the inner tie-rod end on the shaft screw.**

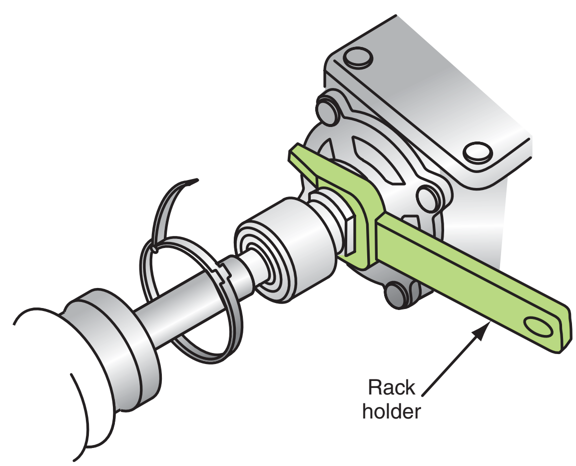


FIGURE 13-20 **Installing the special tool to hold the shaft screw while tightening the inner tie-rod end.**

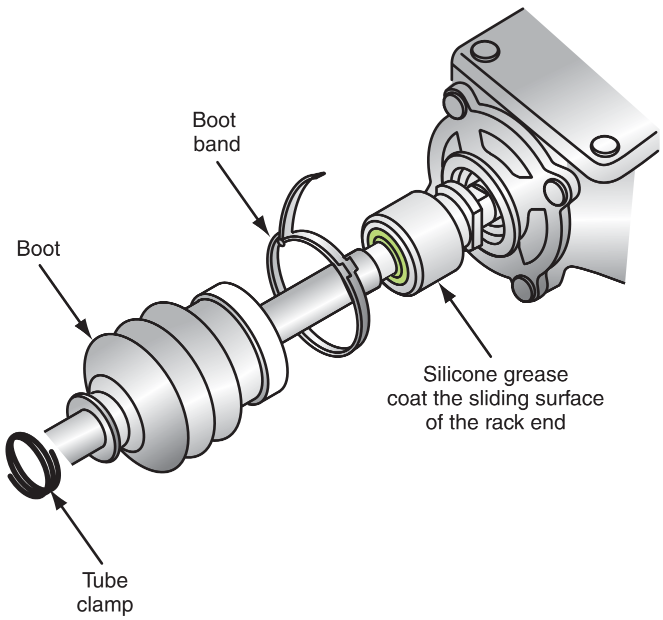


FIGURE 13-21 **Lubricating of the inner tie-rod joint housing.**

CAUTION:
While staking the boot clamps, be careful not to damage the inner tie-rod boots.

5. Bend the lock washer tabs against the flat on the inner tie-rod end.
6. Remove the special holding tool and apply silicone grease to the sliding surface of the tie-rod (Figure 13-21). Place a light coating of silicone grease inside the tie-rod boot.
7. Apply the vehicle manufacturer's recommended grease to the circumference of the inner tie-rod joint housing.
8. Install the boots on the actuator housing; then install the boot bands with the locking tabs properly positioned in relation to the actuator housing (Figure 13-22).
9. Tighten the boot bands and bend both sets of locking tabs over the band (Figure 13-23). Tap lightly on the doubled-over portion of the band to reduce its height and stake the locking tabs firmly.

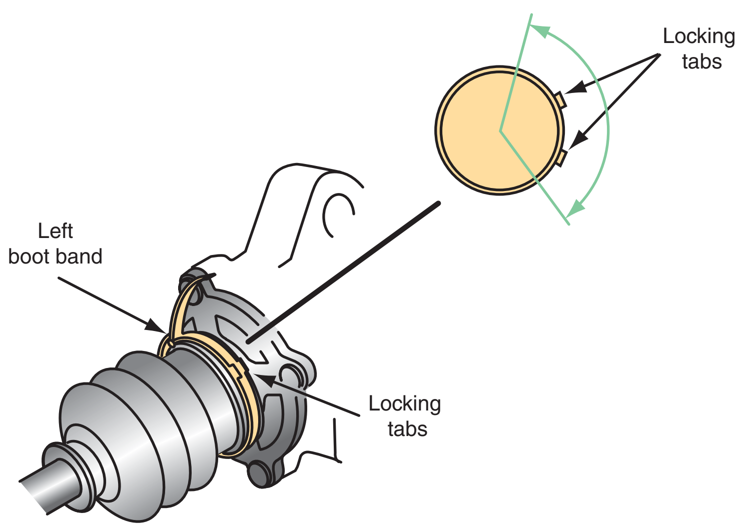


FIGURE 13-22 **Proper boot band position in relation to the actuator housing.**

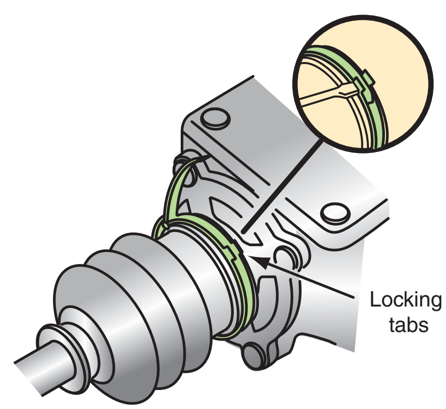


FIGURE 13-23 **Tightening and staking the inner tie-rod boot clamps.**

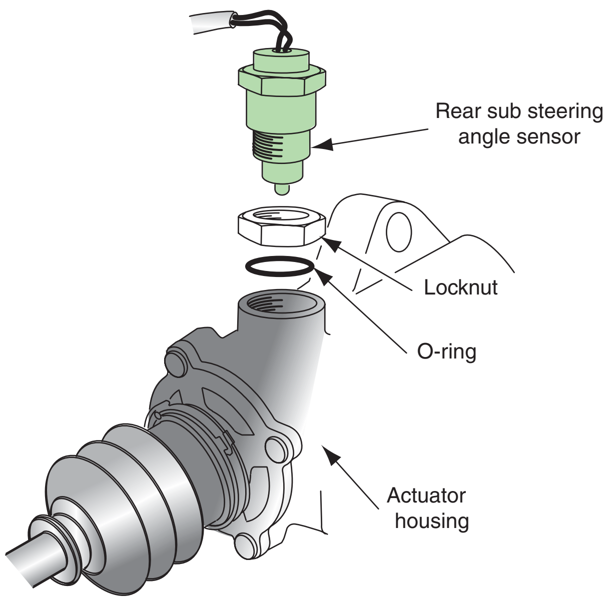


FIGURE 13-24 **Removing the rear sub steering angle sensor.**

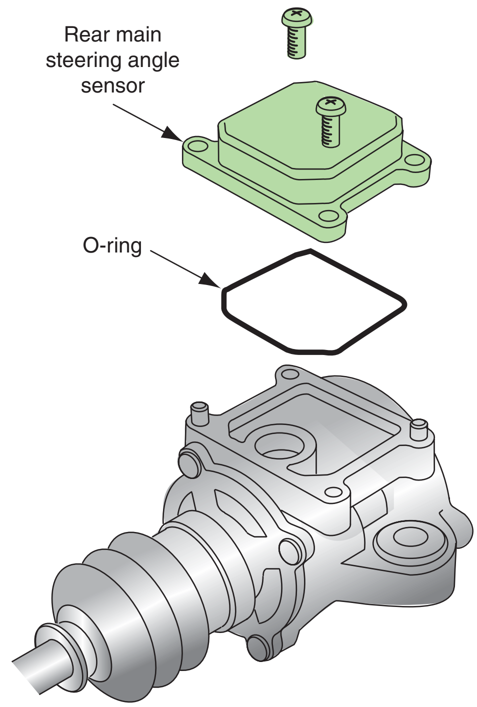


FIGURE 13-25 **Removing the rear main steeing angle sensor.**

The **rear sub steering angle sensor** sends a voltage signal to the 4WS computer in relation to the amount of rack movement in the rear steering actuator.

The **rear main steering angle sensor** sends a voltage signal to the 4WS computer in relation to ball screw rotation in the rear steering actuator.

Remove and Replace Rear Steering Actuator Sensors

Follow these steps to remove and replace the rear sub steering angle sensor and the rear main steering angle sensor:

1. Loosen the rear sub steering angle sensor locknut and rotate the sensor to thread it out of the housing (Figure 13-24). Discard the sensor O-ring.
2. Remove the two mounting bolts in the rear main steering angle sensor, and then remove the sensor from the actuator housing (Figure 13-25). Note the position of the dowel pins, and discard the O-ring.
3. Install the locknut and a new O-ring on the rear sub steering angle sensor.
4. Place a light coating of grease on the O-ring and install the sensor in the actuator housing.
5. Rotate the sensor until it touches the tapered shaft and back it out one-half turn. Tighten the locknut finger tight. Final adjustment of the rear sub steering angle sensor is completed with the actuator installed in the vehicle.
6. Place a light coating of grease on the rear main steering angle sensor O-ring and install this O-ring on the sensor.
7. Install the rear main steering angle sensor and O-ring in the actuator housing with the dowel pins properly positioned, and tighten the mounting bolts to the specified torque.

SERVICE TIP: Cover the rear main steering sensor and rear sub steering sensor openings in the actuator housing with masking tape or its equivalent to keep dirt and foreign material out of the actuator housing.

Installing Rear Steering Actuator

Follow these steps for rear steering actuator installation:

1. Install the rear steering actuator and the four mounting bolts and bracket. The arrow on the bracket must face upward (Figure 13-26).
2. Tighten the rear steering actuator mounting bolts to the specified torque.
3. Reconnect the tie-rod ends to the steering arms and tighten the castelated nut to the specified torque. If necessary, tighten the nut slightly to align the nut slots with the tie-rod pin hole.

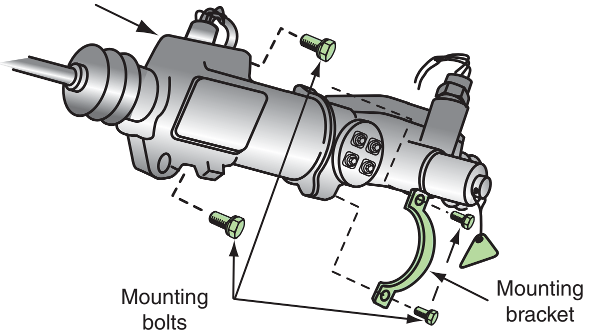


FIGURE 13-26 **Installing the rear steering actuator, four mounting bolts, and bracket.**

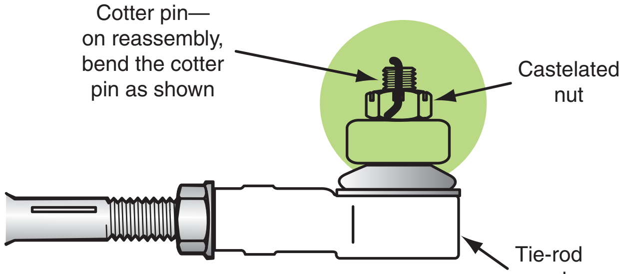


FIGURE 13-27 **Proper installation of cotter pin in the tie-rod end.**

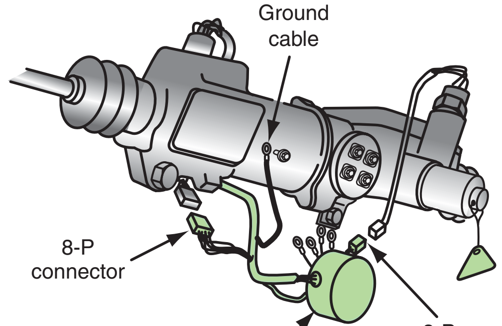


FIGURE 13-28 **Installing wiring connectors on the rear steering actuator.**

CAUTION:
Tighten the castelated nut on the tie-rod ends to the specified torque, and then tighten these nuts enough to align the slots in the nut with the hole in the tie-rod pin. Do not loosen the nut to align the nut slots with the tie-rod pin hole. If this nut is loosened to align the slot with the hole, the tie-rod end may become loose in service.

4. Install the cotter pin in the nut and tie-rod end pin openings, and bend one leg of the cotter pin downward over the nut. Bend the other cotter pin leg upward over the top of the tie-rod end pin (Figure 13-27).
5. Check all the wiring connectors for contamination and clean as necessary. Install all the wiring connectors on the rear steering actuator and tighten all the terminal nuts to the specified torque (Figure 13-28).
6. Install the terminal cover on the rear main steering sensor terminals. Remove the rear steering lock pin and install the cap bolt and washer. Leave the steering actuator cover removed until after the final rear steering actuator adjustments.

Photo Sequence 24 shows a typical procedure for diagnosing an electronically controlled four-wheel steering system.

Diagnosis of Four-Wheel Active Steering (4WAS) System

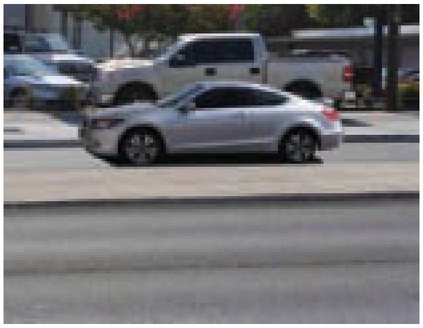
Service Precautions Related to the Supplemental Restraint System (SRS)

The SRS contains air bags in different locations and seat belt pre-tensioners. Improper service procedures may result in unintended air bag deployment and personal injury. To avoid personal injury and/or rendering the SRS inoperative, all precautions recommended by the vehicle manufacturer must be observed. These precautions include the following:

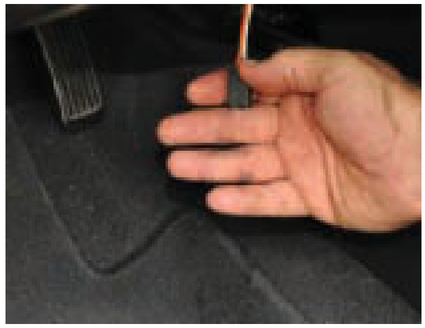
1. Never use any electrical test equipment on any circuit unless this equipment is recommended in the vehicle manufacturer's service manual.
2. Use only service procedures recommended by the vehicle manufacturer.

PHOTO SEQUENCE 24

Typical Procedure for Diagnosing an Electronically Controlled Four-Wheel Steering System

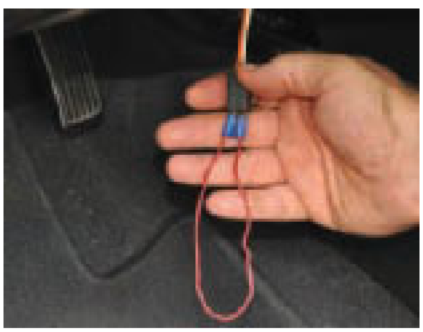


P24-1 **Road test the vehicle to check 4WS operation and indicator light.**

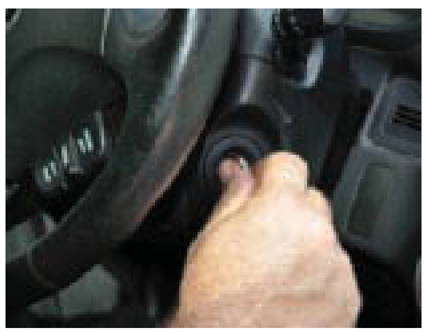


P24-2 **Lower the vehicle and locate the service check connector behind the center console.**

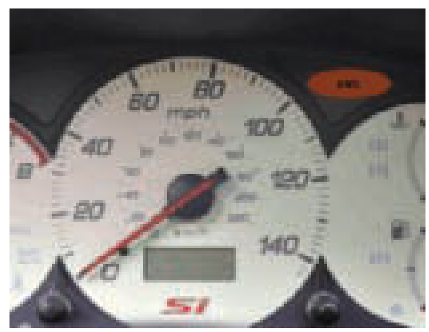
P24-3 **Look up the diagnostic procedure and trouble codes in the car manufacturer's service manual.**



P24-4 **Connect a jumper wire between the terminals in the service check connector.**



P24-5 **Turn on the ignition switch.**



P24-6 **Observe the 4WS indicator light flashes to obtain the fault codes.**

P24-7 **Turn off the ignition switch.**

P24-8 **Remove the jumper wire from the service check connector.**

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Chapter 13, page 315

3. If heavy vibration occurs near a SRS system sensor while the ignition switch is on or the engine is running, air bag deployment may occur. When using air or electric power tools and hammers, always turn the ignition switch Off, disconnect the negative battery cable followed by the positive battery cable, and wait 3 minutes before proceeding with the service work.
4. To avoid accidental air bag deployment when working on the electrical system, turn the ignition switch Off, disconnect both battery cables, and wait 3 minutes.

Service Precautions Related to Electronic Control Unit (ECU) Replacement

Before removing and replacing any ECU, turn the push-button ignition switch to the Lock position, and then disconnect negative battery cable followed by the positive battery cable. After the replacement control unit is installed, be sure all electrical connectors are properly connected and all related wiring harness is in satisfactory condition. Then reconnect the positive cable followed by the negative cable. Use the vehicle manufacturer's recommended scan tool to perform a self-diagnosis on the replacement control unit.

Safety Precautions Related to the Steering Lock Unit

A number of vehicles are equipped with a push-button ignition switch and a steering lock that engages if the battery is disconnected or discharged. If steering wheel rotation is required with the steering lock engaged, follow these steps:

1. Connect both battery cables.
2. If the battery is discharged, use jumper cables connected from a booster battery to the battery terminals with the correct polarity to provide battery voltage to the electrical system.
3. Turn the push-button ignition switch to the ACC position. This action releases the steering lock.
4. Disconnect the negative battery cable followed by the positive battery cable. The steering lock will remain released with both battery cables disconnected, and steering wheel rotation is possible.
5. When the service work is completed, reconnect the positive battery cable followed by the negative cable. With the brake pedal released, turn the push-button ignition switch from the ACC position to the On position, and then to the Lock position. The steering lock will be engaged when the ignition switch is moved to the Lock position. Use the vehicle manufacturer's recommended scan tool to perform a self-diagnosis of all control units in the system being serviced.

Preliminary Diagnosis and Visual Inspection

When diagnosing the 4WAS system, the first step is to identify the complaint. Questioning the customer regarding the vehicle operation often helps to identify the complaint. A vehicle road test may be necessary to experience and determine the exact complaint. After the complaint is identified, the next step is to visually inspect the system to identify any defects. When diagnosing the 4WAS system, be sure the power steering fluid level and the belt tension are correct. Inspect all the wiring harness and wiring connectors for damage and corrosion. Be sure all system components such as the front and rear actuators are mounted securely. Check the 4WAS warning light. This light should go out after the engine starts. If the warning light remains On with the engine running, the 4WAS system has an electronic defect. If no defects are found during the visual inspection, further diagnosis is required.

Scan Tool Diagnosis

The ignition switch should be in the Off position when connecting and disconnecting the scan tool. A scan tool may be connected to the DLC to perform these tests:

1. Self-diagnostic tests – retrieves DTCs indicating electronic defects in certain electronic areas.
2. Data monitor tests – reads data from the system components to determine component operation and condition.
3. CAN diagnostic monitor – indicates if CAN transmit/receive communication is satisfactory.
4. Active tests – activates specific system components to determine component operation.
5. ECU part number – identifies the front ECU part number.

Diagnostic Example DTC C1631

The electronic systems on current vehicles contain many DTCs and provide a large number of data items. The lists of DTCs and data items for various electronic systems are provided in the vehicle manufacturer's service manual. We will provide some diagnostic examples to illustrate how the DTCs and data items may be used to diagnose the 4WAS system.

If DTC C1631 is displayed on the scan tool, the DTC list for the front control unit indicates this DTC represents an error in the front ECU or in the voltage supply to the front ECU. To locate the root cause of this defect, follow these steps:

1. Turn the ignition switch Off and disconnect terminal M41 and M42 on the front ECU as illustrated in Figures 13-29 and 13-30. A partial wiring diagram is shown in Figure 13-31.
2. With the ignition switch Off, connect a voltmeter from terminal 11 to ground in terminal M41. The voltmeter should indicate 12 V. When the voltmeter is connected from terminal 15 in connector M42 to ground, the meter should read 0 V.
3. Turn the ignition switch On and the voltage measured from both terminals 11 and 15 to ground should be 12 V.
4. If the voltage reading is low at terminal 11 to ground, check the 40-A fuse and related circuit, and repair as necessary. When the voltage reading is low at terminal 15, check the 10-A fuse and related circuit, and repair as required.
5. Turn off the ignition switch and connect an ohmmeter from terminal 12 in terminal M41 to ground. The meter should read very low resistance if the ground wire is satisfactory. A high meter reading indicates excessive resistance in this wire or wire terminals and connectors. If a high reading is obtained, repair or replace the ground wire from terminal 12 to ground.
6. Connect the ohmmeter leads from terminals 18 to ground and 34 to ground in connector M42. The ohmmeter should indicate a very low reading at each of these connections. If either connection indicates a high ohmmeter reading, repair or replace the ground wires from terminals 18 and 34 to ground.
7. If the meter readings in steps 1 through 7 are satisfactory, replace the front ECU.

Diagnostic Example DTC C1902

If DTC C1902 is obtained on the scan tool, a rear motor current error is indicated. To pinpoint the root cause of this DTC, follow this procedure:

FIGURE 13-29 **Wiring connection M41 front ECU**

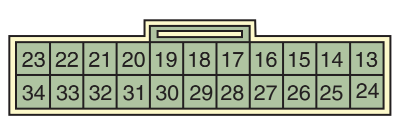

FIGURE 13-30 **Wiring connection M42 front ECU**

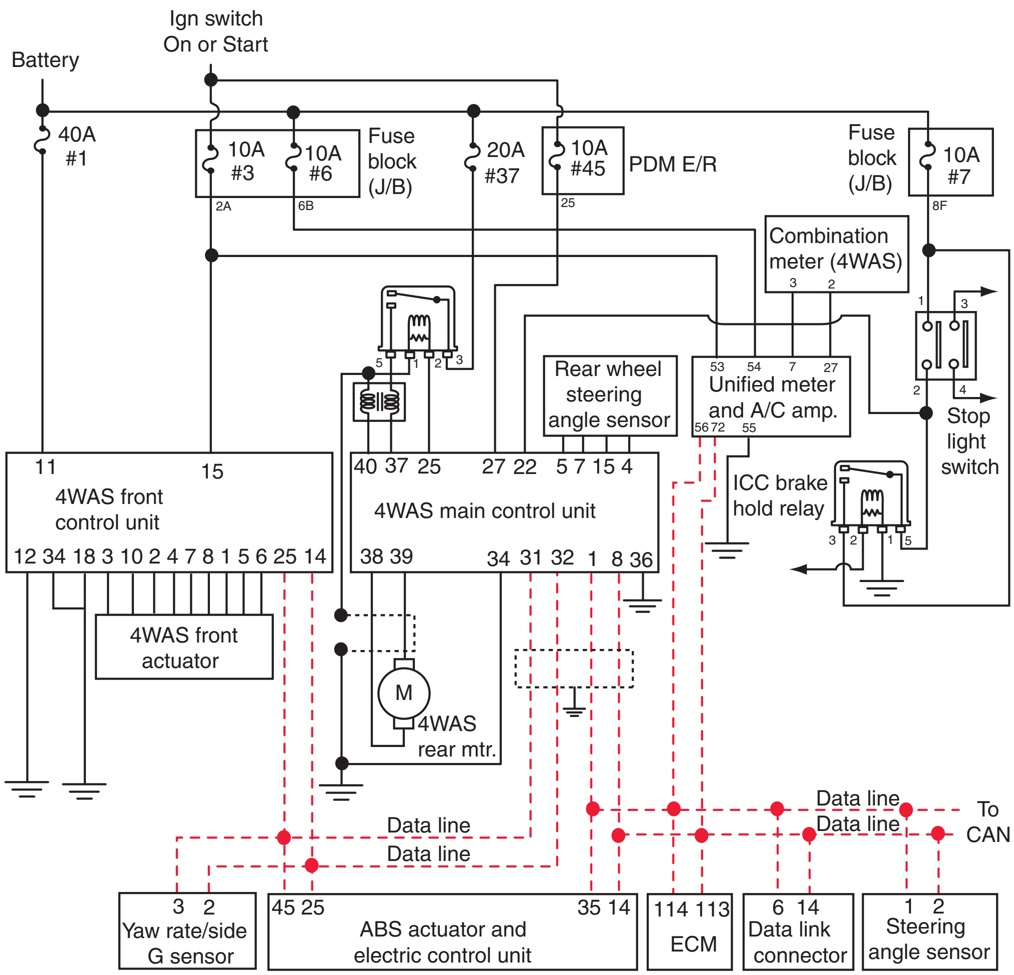

FIGURE 13-31 **4WAS wiring diagram**

1. Turn the ignition switch Off and disconnect wiring connector B54 (Figure 13-32) from the rear ECU and remove wiring connector B36 (Figure 13-33) from the rear motor.
2. Connect a pair of ohmmeter leads from terminal 38 in connector B54 to terminal 1 in connector B36. The ohmmeter should indicate a very low reading. If the ohmmeter reading is high, repair or replace the wire from terminal 1 to terminal 38 as required.
3. Connect a pair of ohmmeter leads from terminal 39 in connector B54 to terminal 2 in connector B36. The ohmmeter should indicate a very low reading. If the ohmmeter reading is high, repair or replace the wire from terminal 2 to terminal 39 as required.
4. Connect a pair of ohmmeter leads from terminals 1 and 2 on the rear motor terminals. A low ohmmeter reading is satisfactory. If the ohmmeter reading is high, replace the rear steering actuator.
5. Reconnect all disconnected connectors and connect the scan tool to the DLC. Using the scan tool, select ACTIVE TEST on the rear ECU and rear actuator. This active test forces the rear ECU to operate the motor in the rear actuator. During the active test, select MOTOR VOLTAGE, MOTOR CURRENT, and MTR CRNT OPE on the scan

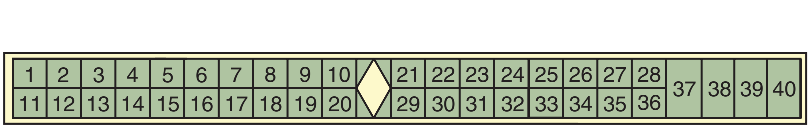

FIGURE 13-32 **Wiring connector B54 rear ECU**

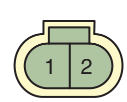

FIGURE 13-33 **Wiring connector B36 rear motor**

tool data monitor. The following readings should be obtained on the scan tool during these selections:

MOTOR VOLTAGE 12 V

MOTOR CURRENT 0–20 A

MTR CRNT OPE – with the steering in the straight ahead position, the rear actuator in the neutral condition –2 to 2A, and rear motor running –20 to 20A.

6. If the readings in step 5 are not within specifications, replace the rear actuator.
7. If all the readings in steps 1 through 5 are satisfactory and DTC 1902 continues to appear, replace the rear ECU.

4WAS Adjustments

If the front ECU or front actuator is replaced or a wheel alignment is performed, a front actuator neutral position adjustment is necessary. Proceed as follows to perform the front actuator neutral position adjustment:

1. With the ignition switch Off, connect the scan tool to the DLC.
2. Be sure the front wheels are in the straight ahead position. Start the engine and select DATA MONITOR and ACTR ROTA ANG on the scan tool.
3. Turn the steering wheel until the ACTR ROTA ANG reading on the scan tool indicates –3.5 to 3.5 degrees.
4. Turn the ignition switch Off.

CASE STUDY

A customer complained about the 4WS indicator light coming on intermittently on a Honda Prelude with an electronic 4WS system. The technician asked the customer about any other steering problems, and the customer reported the car steered normally. The technician road-tested the car, but the 4WS light did not come on, which indicated there were no electronic problems in the system. The customer was concerned about a possible safety hazard while driving this vehicle with the 4WS indicator light illuminated. In reply to this concern, the technician explained to the customer about the fail-safe function in the 4WS system and the rear wheels being centered in this mode.

The technician asked the customer about any recent service work completed on the vehicle. In response to this question, the customer replied that the car had been in a rear end collision recently, and when the body work was completed, the 4WS indicator light problem started occurring. The technician informed the customer that a 4WS system diagnosis and inspection should be performed.

Since the 4WS indicator light was not illuminated, the technician concluded that a trouble code diagnosis would probably not provide any diagnostic answers. However, the technician checked the system for codes in case there was a code caused by abnormal or harsh driving, which would not cause the indicator light to be illuminated.

When the technician raised the vehicle on a hoist, it was clearly visible that many of the rear suspension and body parts had been replaced recently. Even the rear steering actuator cover had been replaced. The technician removed the rear steering actuator cover to inspect the wiring on the actuator. All the wiring connectors were inspected, including the terminals on the rear main steering angle sensor. When the technician inspected the rear sub steering angle sensor wiring harness, he found this harness had been punctured by a sharp object near the sensor. The technician probed the sensor wires at the sensor and connected a pair of ohmmeter leads from each wire at the sensor to the corresponding colored wire in the sensor connector. Each wire showed a normal zero-ohm resistance. The technician repeated these ohmmeter connections and wiggled the wires at the damaged location. On one of the wires, the ohmmeter reading went to infinite while wiggling the wires, indicating an intermittent open circuit.

The technician replaced the rear sub steering angle sensor and performed the electronic neutral check and the rear sub steering angle sensor adjustment. During a road test, the 4WS indicator light did not come on.

Terms to Know

Fail-safe mode

Rear main steering angle sensor

Rear steering center lock pin

Rear sub steering angle sensor

Service check connector

ASE-Style Review Questions

1. While discussing the fail-safe function:
   Technician A says the 4WS indicator light is illuminated during the fail-safe function.
   Technician B says the rear wheels steer normally when the 4WS control unit enters the fail-safe mode.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While discussing the fail-safe function and damper control:
   Technician A says the rear wheels move instantly to the centered position when the 4WS control unit enters the fail-safe mode.
   Technician B says the return spring moves the rear wheels away from the centered position.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. While discussing trouble code diagnosis:
   Technician A says the 4WS system service check connector is located under the driver's seat.
   Technician B says when one of the service check connector terminals is grounded, the 4WS system enters the diagnostic mode.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. While discussing trouble code diagnosis:
   Technician A says many 4WS system trouble codes are cancelled when the ignition switch is turned off.
   Technician B says codes representing problems caused by abnormal or harsh driving conditions do not illuminate the 4WS indicator light.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

5. While discussing rear steering actuator service:
   Technician A says the rear steering actuator is a replacement unit except for tie-rods and sensors.
   Technician B says the arrows on the rear steering actuator brackets must face downward.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

6. All of these statements about rear steering actuators and actuator service are true EXCEPT:
   A. Axial impact on the shaft screw may damage the actuator.
   B. Rotational force on the shaft screw may damage the actuator.
   C. The engine may be started with the rear steering lock pin in place.
   D. The shaft screw must be held with a special tool while loosening the tie-rods.

7. When diagnosing a Quadrasteer system a DTC B1000 is displayed on the scan tool. The most likely reason for this
   DTC is:
   A. A defective steering wheel position sensor.
   B. A defective rear wheel steering motor.
   C. An internal defect in the BCM.
   D. An open circuit in the wiring to the rear steering motor.

8. When performing a Learn Rear Wheel Alignment procedure:
   Technician A says the steering wheel must be centered.
   Technician B says during this procedure the front wheels must be lifted off the shop floor.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

9. A DTC representing a data link defect begins with a:
   A. B. C. P.
   B. C. D. U.

10. When diagnosing a 4WAS with a scan tool:
    Technician A says the CAN diagnostic monitor indicates if transmit/receive communication is satisfactory.
    Technician B says that during the active tests the scan tool activates specific system components.
    Who is correct?

ASE Challenge Questions

1. While discussing electronic 4WS:

   Technician A says jumping the two terminals of the service check connector with the engine off will display DTCs.

   Technician B says jumping the service check connector then starting the engine displays the processor in which the codes are stored.

   Who is correct?

   A. A only C. Both A and B

   B. B only D. Neither A nor B

2. The Honda Prelude 4WS system uses a main and a sub processing unit, each storing 10 trouble codes. If the 4WS light on the dash blinks quickly and repeatedly for three seconds, it means:

   A. A DTC is stored in the main processor.

   B. A DTC is stored in the sub processor.

   C. The system is moving from the main to the sub processor memory.

   D. A DTC sequence will be repeated.

3. Honda Prelude temporary "abnormal or harsh driving" 4WS DTCs range from to .

   A. 07/14 C. 17/24

   B. 70/74 D. 44/47

4. The Honda Prelude 4WS light has gone on and remains on.

   Technician A says that before performing any diagnostic tests, the 10A fuse for the clock radio should be removed.

   Technician B says to retrieve the DTC, the 4WS control unit connector must be disconnected.

   Who is correct?

   A. A only C. Both A and B

   B. B only D. Neither A nor B

5. While discussing electronic 4WS:

   Technician A says that after repairing a defect of the main steering angle sensor in the Honda Prelude 4WS system, fuse #43 must be removed to cancel the code.

   Technician B says the battery terminal must be removed to cancel DTCs in parts of the Honda Prelude 4WS system other than the main steering angle sensor.

   Who is correct?

   A. A only C. Both A and B

   B. B only D. Neither A nor B

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Name ______________________________ Date ____________________

Retrieve Diagnostic Trouble Codes (DTCs), Four-Wheel Steering (4WS) System

Upon completion of this job sheet, you should be able to retrieve diagnostic trouble codes (DTCs) on four-wheel steering (4WS) systems.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task B-19: Test and diagnose components of electronically controlled steering systems using a scan tool: determine necessary action.

Tools and Materials

Jumper wire

Describe the Vehicle Being Worked On:

Year ____________ Make ____________ Model ____________________

VIN ______________________ Engine type and size ____________________

Procedure

Task Completed

1. Be sure the ignition switch is off and remove the dual-terminal service check connector located behind the center console. Connect the two terminals in this connector with a jumper wire.
   Is the jumper wire properly connected? ☐ Yes ☐ No
   Instructor check ______________________________
2. Turn the ignition switch on, but do not start the engine. ☐
3. Observe the 4WS indicator light to read the diagnostic trouble codes (DTCs). Three longer flashes followed by a brief pause and one quicker flash indicates code 31. The codes are given in numerical order. ☐
4. List the DTCs provided with ignition switch on and the engine not running and include the DTC interpretation.
   1. ______________________________
   2. ______________________________
   3. ______________________________
5. Turn the ignition switch off and start the engine while observing the 4WS indicator light in the instrument panel. ☐
6. Does the 4WS indicator light blink once quickly when the ignition switch is turned on?
   4WS light operation: ☐ Satisfactory ☐ Unsatisfactory
   If the 4WS light operation is unsatisfactory, describe the light operation.
   ____
   ____

Task Completed

7. After the quick flash in step 6, did the 4WS indicator light pause for 3 seconds?
4WS light operation: ☐ Satisfactory ☐ Unsatisfactory
If the 4WS light operation is unsatisfactory, describe the light operation.

____

____

8. List the main processor DTCs displayed after the pause in step 7 and include the DTC interpretation.

1. ____
2. ____
3. ____

9. Did the 4WS indicator light pause for 1.6 seconds after the DTCs displayed in step 8?
☐ Yes ☐ No
4WS light operation: ☐ Satisfactory ☐ Unsatisfactory
If the 4WS light operation is unsatisfactory, describe the light operation.

____

____

10. Did the 4WS indicator light blink quickly for three seconds to indicate a separation between the main and sub processor codes? ☐ Yes ☐ No
4WS light operation: ☐ Satisfactory ☐ Unsatisfactory
If the 4WS light operation is unsatisfactory, describe the light operation.

____

____

11. Did the 4WS indicator light pause for 1.6 seconds? ☐ Yes ☐ No
4WS light operation: ☐ Satisfactory ☐ Unsatisfactory
If the 4WS light operation is unsatisfactory, describe the light operation.

____

____

12. List the sub processor DTCs displayed after the pause in step 11, and include the DTC interpretation.

1. ____
2. ____
3. ____

13. Did the 4WS indicator light pause for 3 seconds and then repeat the cycle? ☐ Yes ☐ No
4WS light operation: ☐ Satisfactory ☐ Unsatisfactory
If the 4WS light operation is unsatisfactory, describe the light operation.

____

____

14. On the basis of all the DTCs displayed, state the required diagnostic procedure to locate the exact cause of the defect(s) and explain the reasons for your diagnosis.

____

____

Instructor's Response ____

____

____

____

Name ______________________________ Date ____________________

Perform a Learn Rear Wheel Alignment Procedure on a Quadrasteer System

Upon completion of this job sheet, you should be able to perform a Learn Rear Wheel Alignment procedure on a Quadrasteer system.

NATEF Correlation

This job sheet is correlated with NATEF Automotive Suspension and Steering Task B-19: Test and diagnose components of electronically controlled steering systems using a scan tool; determine necessary action.

Tools and Materials

Vehicle with a Quadrasteer system

Compatible scan tool

Describe the Vehicle Being Worked On:

Year ______________ Make ______________ Model ______________________

VIN ________________________ Engine type and size ______________________

Procedure

Task Completed

1. Turn on the ignition switch and start the engine.
   Engine running, ☐ Yes ☐ No
2. Connect the scan tool to the DLC under the dash.
   Scan tool properly connected to the DLC, ☐ Yes ☐ No
3. Center the steering wheel.
   Steering wheel properly centered, ☐ Yes ☐ No
4. Lift the rear of the vehicle so the rear tires are a few inches off the shop floor. Be sure the chassis is securely supported on safety stands, and the rear wheels are centered.
   Rear wheels raised off the shop floor, ☐ Yes ☐ No
   Chassis properly supported on safety stands, ☐ Yes ☐ No
   Steering wheel centered, ☐ Yes ☐ No
5. Select the Learn Alignment menu on the scan tool.
   Learn Alignment displayed on the scan tool, ☐ Yes ☐ No
6. Follow the directions on the scan tool. When directed, the front wheels must be turned 90° to the left and 90° to the right, and then returned to the center position.
   Steering wheel rotated 90° in each direction, ☐ Yes ☐ No
   Steering wheel centered, ☐ Yes ☐ No
7. Press the Continue button on the scan tool until the Learn Alignment procedure is completed.
   Learn Alignment procedure properly completed, ☐ Yes ☐ No
8. Use the scan tool to erase the rear wheel steering DTCs.
   DTCs erased, ☐ Yes ☐ No

Task Completed

9. Shut off the ignition, disconnect the scan tool, and lower the rear wheels onto the shop floor.
Ignition shut off and scan tool disconnected, ☐ Yes ☐ No
Vehicle lowered onto shop floor, ☐ Yes ☐ No

Instructor's Response ____

____

____

____

Name ______________________________ Date ____________________

Quadrasteer Diagnostic System Check

Upon completion of this job sheet, you should be able to perform a Diagnostic System Check on a Quadrasteer System.

NATEF Correlation

This job sheet is correlated with NATEF Automotive Suspension and Steering Task D-4: Diagnose, inspect, adjust, repair or replace components of electronically controlled steering systems (including sensors, switches, and actuators), initialize system as required.

Tools and Materials

Vehicle with a Quadrasteer system

Compatible scan tool

Describe the Vehicle Being Worked On:

Year ______________ Make ______________ Model ____________________

VIN ________________________ Engine type and size ____________________

Procedure

Task Completed

1. With the ignition switch off, connect a scan tool to the DLC under the dash.
   Scan tool properly connected to the DLC, ☐ Yes ☐ No
2. Turn on the ignition switch, and select Rear Wheel Steering Control Module on the scan tool. If the scan tool does not communicate with this module, check the scan tool electrical connection and the data links. Be sure the scan tool communicates with all the other modules on the vehicle.
   Proper scan tool communication with rear wheel steering control module and other modules on the vehicle, ☐ Yes ☐ No
3. Access the Class 2 Power Mode on the scan tool, and rotate the ignition switch through all positions while observing the scan tool. The engine may start with the ignition switch in the Start position. The ignition switch position displayed on the scan tool should match the actual ignition switch position.
   Actual ignition switch positions match displayed ignition switch positions on the scan tool, ☐ Yes ☐ No
4. Select the Display DTCs function on the scan tool and then select Rear Wheel Steering Control Module to display the DTCs related to the 4WS system. Select all the other modules on the vehicle, and display any DTCs stored in these modules. Record all DTCs.
   Rear wheel steering control module DTCs ______________________________
   ____
   DTCs from other modules ______________________________
   ____

Task Completed ________

5. Are there any DTCs beginning with a U? These DTCs relate to data link problems and must be repaired before proceeding with 4WS diagnosis.
DTCs beginning with a U ____

6. Does the scan tool display DTC B1000? This DTC indicates an internal defect in the body control module (BCM) and causes the BCM to refuse all additional inputs.
DTC B1000 displayed, ☐ Yes ☐ No

Instructor's Response ____
____
____
____

Chapter 14

Frames and Frame Damage

Upon completion and review of this chapter, you should be able to understand and describe:

- The purposes of a vehicle frame.
- Different types of frame construction.
- Different types of frame designs.
- Unitized body construction, and explain how this body design obtains its strength.
- Directional stability.
- Vehicle tracking, and explain how the four wheels on a vehicle must be positioned to obtain proper tracking.
- Wheelbase, and explain how the wheels on a vehicle must be positioned to provide correct wheelbase.
- Setback on a front wheel, and explain the effect that setback has on vehicle steering.
- Rear axle offset, and describe the effect of this problem on steering control.
- Rear axle sideset and explain the effect of rear axle sideset on steering control.
- Side sway frame damage.
- Frame sag.
- Frame buckle.
- A diamond-frame condition.
- Frame twist.
- Aluminum spaceframe construction.

Introduction

The frame in a vehicle may be compared to the skeleton in the human body. Without the skeleton, a human body would not be able to stand erect. Likewise, if a vehicle did not have a frame, it could not support its own weight or the weight of its passenger or cargo load. The vehicle frame:

1. Enables the vehicle to support its total weight.
2. Enables the vehicle to absorb stress from road irregularities.
3. Enables the vehicle to absorb torque from the engine and drive wheels.
4. Provides a main member for attachment of body and other components.

The frame, together with the front and rear suspension systems, must position the wheels properly to minimize tire tread wear and provide accurate steering control.

In a **channel frame**, each side of the frame is made from a U-shaped steel channel.

In a **complete box frame**, each side of the frame forms a metal box.

A **tubular frame** member is formed in an oval shape or circle.

Hydro-forming is the process of using extreme fluid pressure to shape metal.

In a **ladder frame design**, cross members are mounted between the sides of the frame, and the cross members are similar to rungs on a ladder.

Types of Frames and Frame Construction

Frame Construction

Vehicle frame construction may contain three types of steel members: **channel** (partial box) **frame, complete box frame**, or **tubular frame** (Figure 14-1). On modern vehicles, most frames include all three types.

Compared to a channel frame or tubular frame, the complete box frame has increased torsional rigidity and improved crash performance. Therefore, in many frames the front section is a complete box design and the other part of the frame is a channel design. Some frames have X-shaped bracing at the rear of the frame for increased strength. Many vehicles now have frames or partial frames that are manufactured by a **hydro-forming** process. Hydro-formed frames are considerably more rigid than frames manufactured by heat-treating. Therefore, hydro-formed frames reduce the flexing of the frame and body components, which reduces squeaks and rattles to decrease noise, vibration, and harshness (NVH). Hydro-formed frames also provide more stable wheel position, which improves steering quality and reduces tire tread wear.

Ladder-Type Frames

The **ladder frame design** is used on trucks and full-size vans. In this type of frame, the side rails have very little offset and are in a straight line between the front and rear wheels. The ladder-type frame has more cross members for increased load-carrying capacity and rigidity (Figure 14-2).

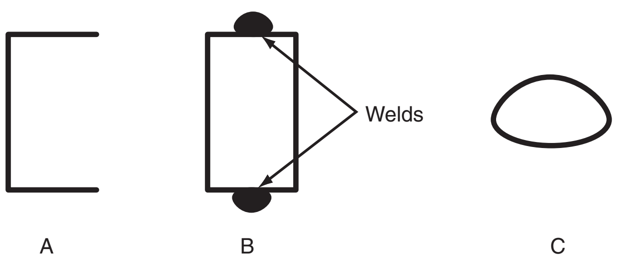

FIGURE 14-1 **Types of frame construction: (A) channel or partial box, (B) complete box, (C) tubular cross member.**

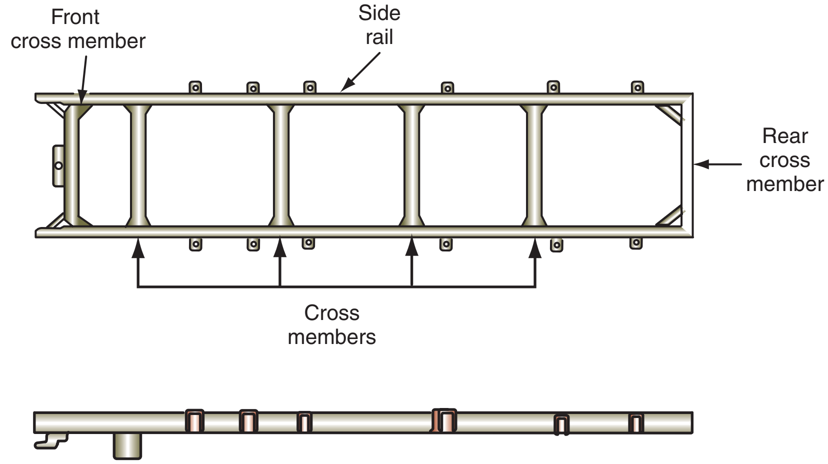

FIGURE 14-2 **Ladder-type frame.**

Perimeter-Type Frames

The **perimeter-type frame** is used in some rear-wheel-drive cars. This type of frame forms a border around the passenger compartment. The frame rails are stepped inward at the cowl area to provide increased strength, which supports the engine mounts and front suspension. This inward step at the cowl area also provides room for movement of the front wheels. Lateral support is provided by cross members welded between the frame rails near the front and rear of the frame. A transmission support member is welded or bolted between the frame rails at the back of the transmission. The rear frame kickup side rails support the rear suspension and the rear portion of the body weight. A front torque box is positioned just ahead of the transmission support member, and a rear torque box is located in front of the rear frame kickup side rails (Figure 14-3). These torque boxes are designed to absorb most of the impact during a side collision and thus reduce damage to other body components. The torque boxes also provide some protection for the vehicle occupants during a side collision.

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The body components are bolted to the frame, but rubber insulating bushings are positioned between the body and frame mounting locations. These bushings help prevent the transfer of road noise and vibration from the suspension and frame to the body and vehicle interior. Rubber insulating mounts are positioned between the engine and transmission and the frame mounting positions. These engine and transmission mounts reduce the transfer of engine vibration to the frame, body, and vehicle interior. Many suspension components are also connected to the frame through rubber insulating bushings to reduce the transfer of harshness and vibration from the suspension to the frame while driving over road irregularities.

During the manufacturing process, most manufacturers apply a special coating to the frame to help prevent rust and corrosion. For example, many light-duty truck frames are coated with epoxy or wax. An epoxy-coated frame is black and very smooth, whereas a wax-coated frame is gray and sticky. If these coatings are scratched or damaged, frame rusting and corrosion may occur.

Aluminum Spaceframes

Some sports cars are equipped with aluminum spaceframes (Figure 14-4). The aluminum spaceframe is manufactured using a hydroforming process. In theory, an aluminum frame must have three times the thickness of a steel frame to have the same strength as a steel frame. During the aluminum spaceframe–manufacturing process, a manufacturer adds thickness only where needed for adequate strength. As a result, the aluminum spaceframe has an average thickness of 1.9 times that of a comparable steel frame. This aluminum frame weighs 285 lb (129 kg), which is 136 lb (62 kg) lighter than a steel frame. Reducing vehicle weight improves fuel economy and vehicle performance.

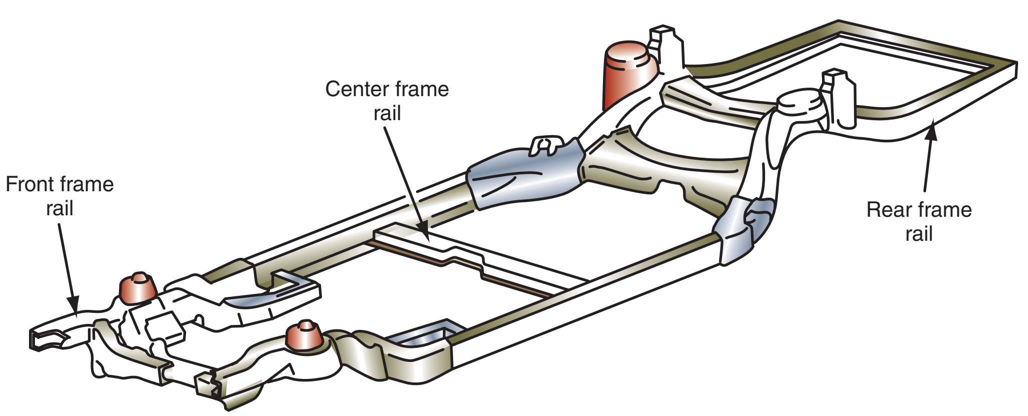

FIGURE 14-3 **Perimeter-type frame components.**

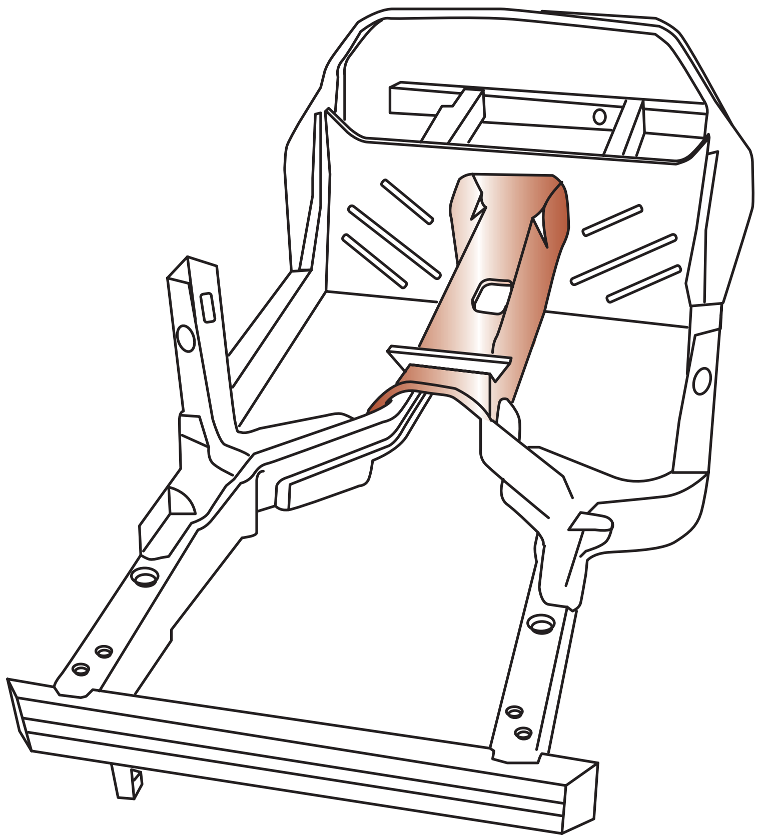

FIGURE 14-4 **Aluminum spaceframe.**

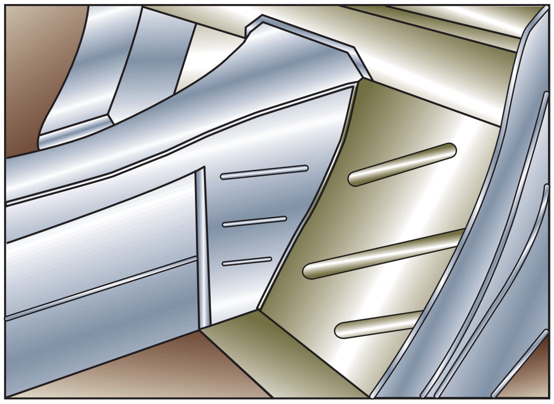

FIGURE 14-5 **Laser welding on aluminum spaceframe tunnel.**

Laser welding is used extensively on the tunnel in the aluminum spaceframe rather than spot welding (Figure 14-5). Laser welding adds stiffness and provides an improved seal compared with that provided by spot welding. Laser welding uses less heat per length of weld, which results in reduced aluminum distortion.

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Unitized Body Design

Most front-wheel-drive cars have a **unitized body.** In this body design, the frame and body are combined as one unit, and the external frame assembly is eliminated. The strength and rigidity of the body is achieved by body design rather than by having a heavy steel frame

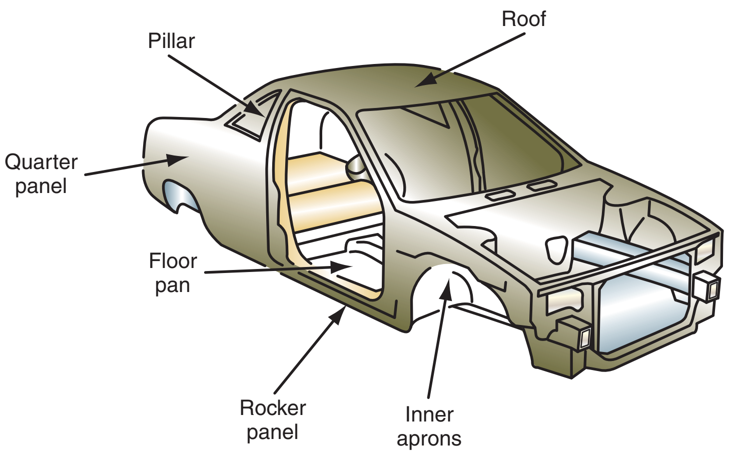

FIGURE 14-6 **Unitized body design.**

to support the body. In the unitized body design, body sheet metal is fabricated into a box design. Body strength is obtained by shape and design in place of mass and weight of metal in vehicles with a separate frame.

All the members of a unitized body are load-carrying components. The floor pan, roof, inner aprons, quarter panels, pillars, and rocker panels are integrally joined to form a unitized body (Figure 14-6).

Most unitized bodies have bolt-on partial frames at the front and rear of the vehicle. Some of the components in a unitized body are made from **high-strength steels (HSS)** to provide additional protection in a collision. Ultra-HSS may be used in such unitized body components as door beams and bumper reinforcements. The unitized body has a complex design that spreads collision forces throughout the body to help protect the vehicle occupants.

Vehicle Directional Stability

The front and rear suspension systems are attached to the frame, partial frame, or unitized body. Therefore, the frame or unitized body must support the suspension systems properly to provide directional stability. Vehicle **tracking** is the parallel relationship between the front and rear wheels during forward vehicle motion. To provide proper tracking, each front wheel must be the same distance from the vehicle centerline, and each rear wheel must be an equal distance from the same centerline. The distance between the front wheels and the distance between the rear wheels does not necessarily have to be the same, but all four wheels must have a parallel relationship to provide proper tracking (Figure 14-7).

A Bit of History

During the late 1940s, American Motors Corporation introduced the unitized body design in the United States. Some of these first-generation unitized bodies did not have partial frames. However, unitized bodies did not become popular until 1980 and 1981 with the introduction of General Motors X cars, Chrysler K cars, and other front-wheel-drive cars. These front-wheel-drive cars have partial frames and may be referred to as second-generation unitized bodies.

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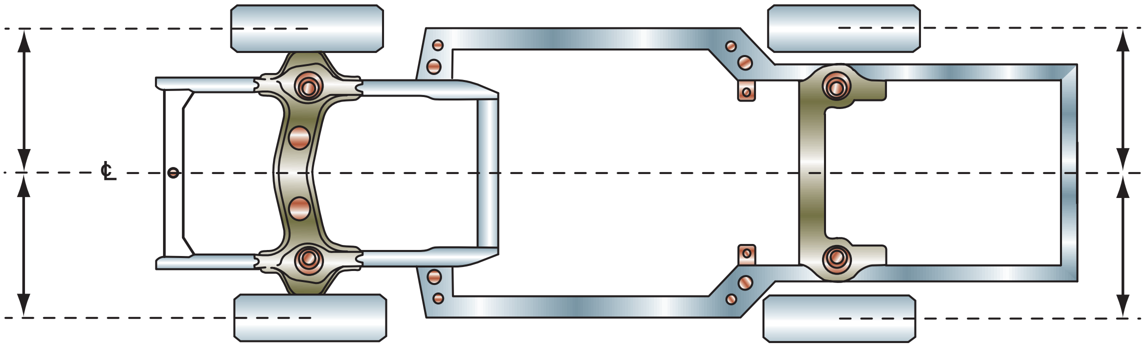


FIGURE 14-7 **Front and rear wheels must be the same distance from the vehicle centerline to provide proper tracking.**

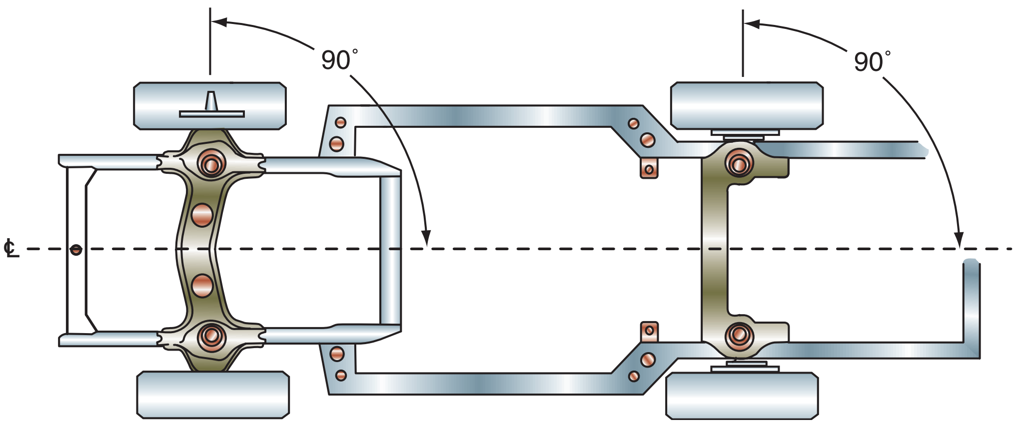


FIGURE 14-8 **To provide accurate wheelbase measurement, the front spindle centerlines and the rear axle centers must be at a 90° angle to the vehicle centerline.**

Directional stability refers to the tendency of a vehicle to remain in the straight-ahead position when driven straight ahead on a reasonably smooth, straight road.

The vehicle **wheelbase** is the distance between the centers of the front and rear wheels. To provide an accurate wheelbase measurement, the centers of the front spindles and the centers of the rear axles must be square with the centerline of the vehicle (Figure 14-8). For this condition to exist, the front and rear axle centers must be at a 90° angle in relation to the vehicle centerline, and the wheelbase measurements must be equal on each side of the vehicle. Equal wheelbase measurements on each side of the vehicle and proper tracking are absolutely essential to providing **directional stability.**

Vehicle Tracking

Wheel Setback

Front **wheel setback** occurs when the spindle on one front wheel is rearward in relation to the other front wheel. The centerline of each front wheel is still at a 90° angle to the vehicle centerline, but the front wheels no longer share the same centerline (Figure 14-9).

When left front wheel setback occurs, the vehicle has a tendency to steer to the left as it is driven straight ahead. Under this condition, the driver has to continually turn the steering wheel to the right to keep the vehicle moving straight ahead.

The term dogtracking may be applied to axle offset or sideset, because in either of these conditions the rear wheels are not parallel to the front wheels. Similarly, many dogs run down the street with their rear ends out of line with their front ends.

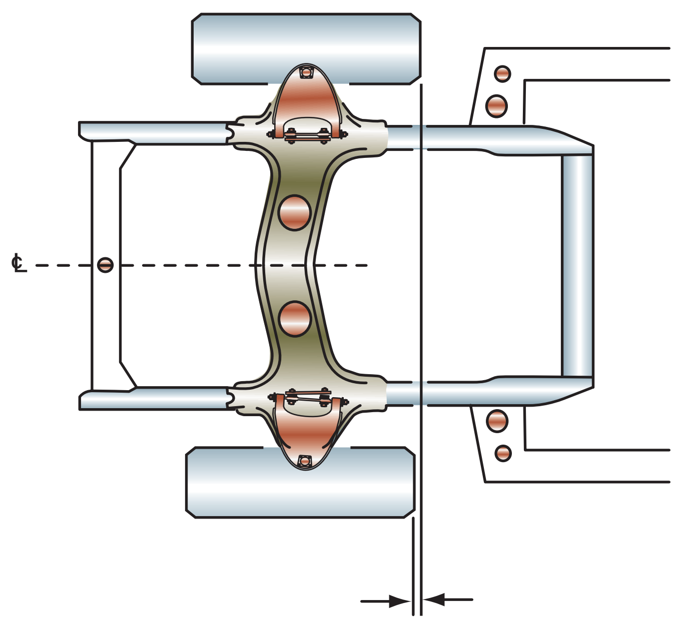


FIGURE 14-9 **Setback occurs when one front wheel is positioned rearward in relation to the other front wheel.**

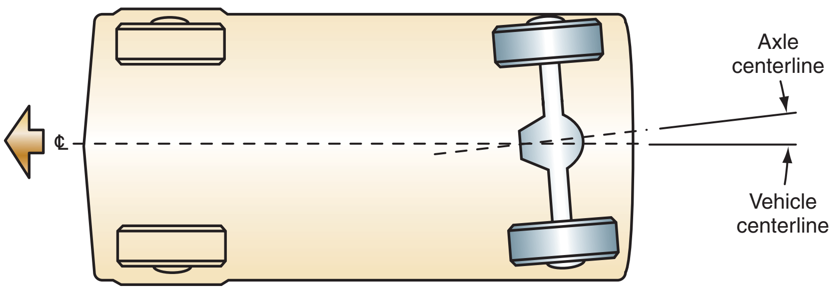


FIGURE 14-10 **Rear axle offset occurs when the rear axle is rotated so the axle centerline and the vehicle centerline are no longer at a 90° angle.**

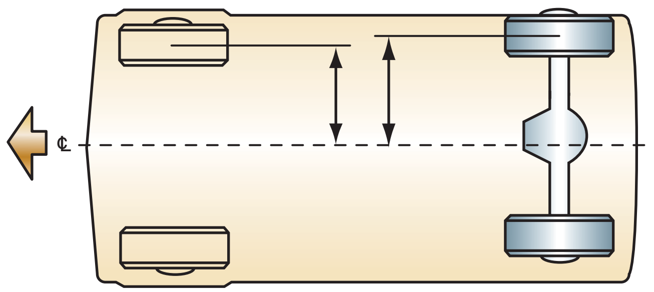


FIGURE 14-11 **Axle sideset occurs when the rear axle moves inward or outward and the axle centerline remains at a 90° angle in relation to the vehicle centerline.**

Axle Offset

If the rear axle is rotated, the **axle thrustline** is no longer at a 90° angle to the **geometric vehicle centerline** (Figure 14-10). This condition is referred to as **axle offset.** When the left side of the rear axle is rotated rearward, the steering pulls continually to the right. Under this condition, the driver has to turn the steering wheel to the left to keep the vehicle moving straight ahead.

The **axle thrustline** is a line extending forward from the center of the rear axle at a 90° angle.

Axle Sideset

When **axle sideset** occurs, the rear axle moves inward or outward, but the axle and vehicle centerlines remain at a 90° angle in relation to each other (Figure 14-11). Under this condition, the front-to-rear axle thrustline is no longer at the geometric vehicle centerline. This condition also causes steering pull. The vehicle frame or unitized body and the front and rear suspension systems must have proper tracking and equal wheelbase measurements on each side of the vehicle to provide directional stability and steering control.

The **geometric vehicle centerline** refers to the front-to-rear centerline of the vehicle body. The centerlines of the front and rear axles should be positioned on this geometric centerline.

Types of Frame Damage

Side Sway

AUTHOR'S NOTE: It has been my experience that frame damage is most commonly caused by abuse, and this problem is usually encountered on light-duty trucks or sport utility vehicles (SUVs). The frame damage may occur when the vehicle is overloaded and/or driven abusively on extremely rough terrain. Another common cause of frame damage is from a vehicle collision. In this case, the frame damage was likely ignored or overlooked during the body repairs. Regardless of the cause, frame damage usually results in excessive tire tread wear and steering complaints.

CAUTION: When attaching any type of additional equipment to a vehicle frame, always try to use the holes that already exist in the frame. Do not drill holes in a vehicle frame except at locations specified by the vehicle manufacturer, and do not attach additional equipment to a vehicle frame unless this procedure is approved by the vehicle manufacturer.

CAUTION: Do not apply heat to a vehicle frame with an acetylene torch. When the metal is heated to a cherry red, the frame may be weakened.

Side sway is a lateral misalignment that affects the frame or body centerline.

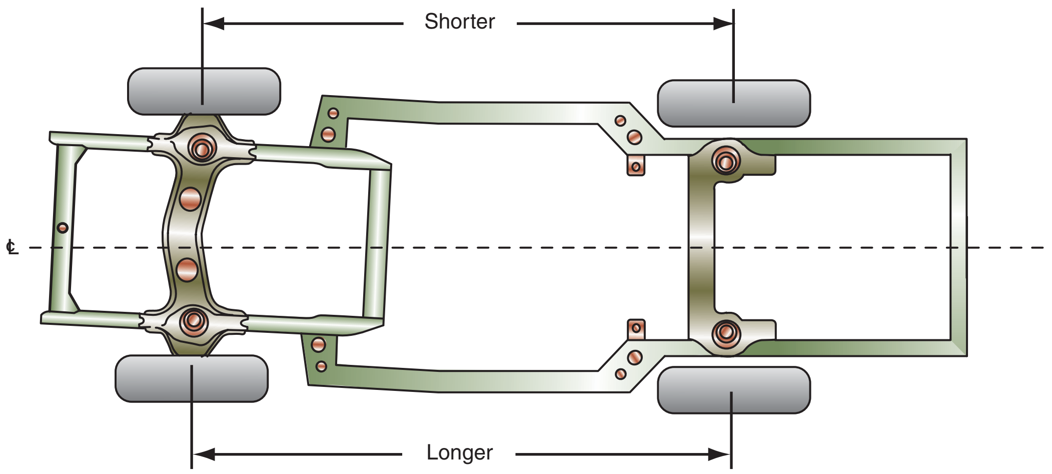


FIGURE 14-12 **Side sway frame condition caused by collision damage.**

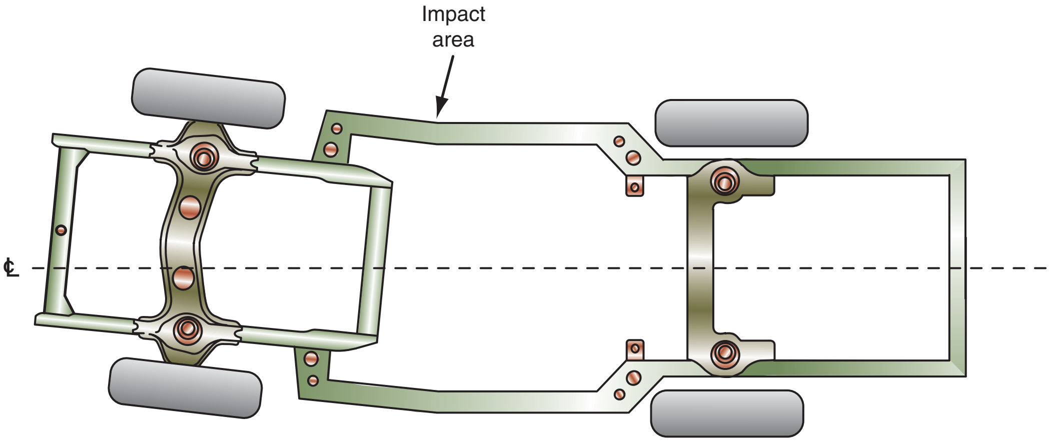


FIGURE 14-13 **When a frame has overall side sway damage, it is slightly V-shaped.**

Side sway on the front or rear of a vehicle is usually the result of the vehicle being involved in a collision that pushes the front or rear frame sideways (Figure 14-12). Under this condition, the wheelbase on one side of the vehicle is longer than the opposite side. This side sway condition causes the steering to pull to the side with the shorter wheelbase.

Overall side sway occurs when the vehicle is hit directly on the side near the center in a collision. A vehicle frame is slightly V-shaped when it has overall side sway damage (Figure 14-13).

WARNING: Some types of frame damage cause steering pull when driving straight ahead, and this steering pull is increased during hard braking. Therefore, frame damage can create a safety hazard that leads to a collision involving personal injury and vehicle damage.

Sag

Frame sag usually occurs when the vehicle is involved in a direct front or rear collision. When this condition is present, the front and/or rear frame rails are moved upward in relation to the center of the frame (Figure 14-14). If one side of the vehicle sustained more collision force than the opposite side, the left and right wheel base measurements will also likely be different.

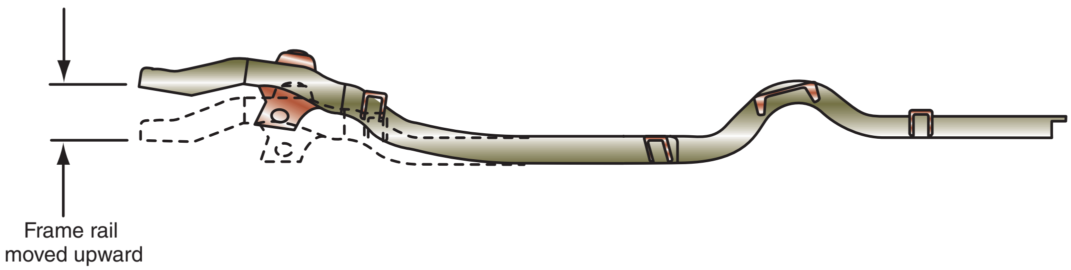


FIGURE 14-14 **Frame sag caused by direct front or rear collision damage.**

The front cross member may receive sag damage in a collision. When this member is sagged, the upper control arms move closer together on a short-and-long arm suspension. If a MacPherson strut front suspension is sagged, the strut towers are moved closer together. In either type of front suspension, a sagged condition moves the top of the wheels inward to a **negative camber** position.

Negative camber occurs when the camber line through the center of the tire and wheel is tilted inward compared with the true vertical centerline of the tire and wheel.

Frame Buckle

A buckle condition exists when the distance from the cowl to the front bumper is less than specified, or the measurement from the rear wheels to the rear bumper is less than specified (Figure 14-15). Frame buckle is caused by a direct front or rear collision. In many cases of **frame buckle,** the wheelbase is reduced on one or both sides of the vehicle. This type of collision damage may cause the sides of the vehicle to bulge outward, especially on unibody cars. Under this condition, the side rails and door openings are distorted.

Frame buckle is accordion-shaped damage on the front or rear of the frame, which causes the distance to be reduced between the cowl and front bumper or between the rear wheels and rear bumper. Frame buckle may be called frame crush or mash.

Diamond-Frame Condition

A **diamond-frame condition** is present when collision damage causes a frame to be out of square. Under this condition, the frame is shaped like a parallelogram (Figure 14-16). If the right rear wheel is driven rearward in relation to the left rear wheel, the rear suspension steers the vehicle to the right, and this forces the front end of the vehicle to the left. Under this

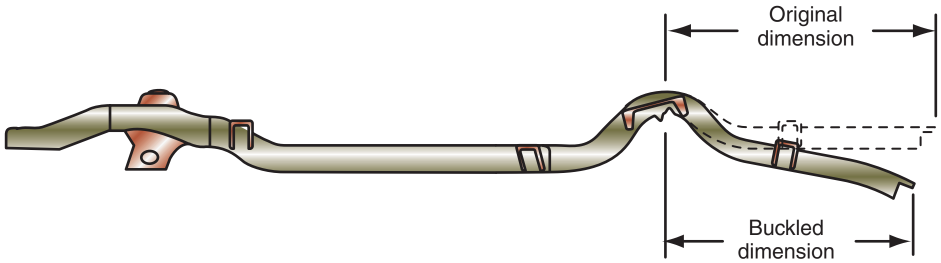


FIGURE 14-15 **Rear frame buckle.**

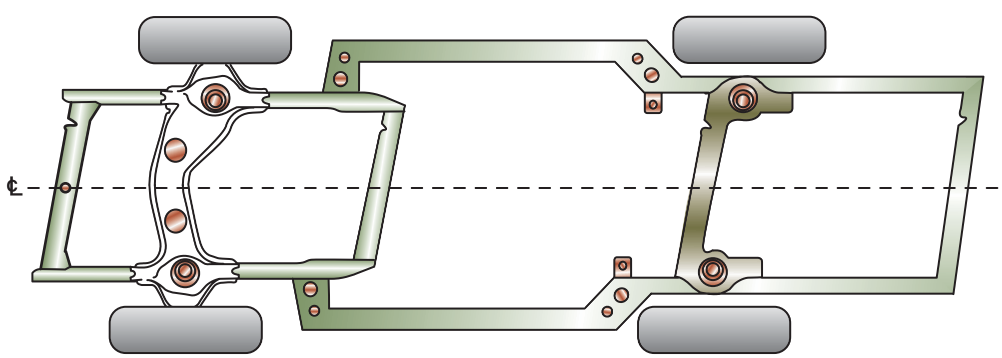


FIGURE 14-16 **Diamond-frame condition.**

condition, the steering wheel must be held continually to the right to overcome the steering pull to the left. A diamond condition usually occurs on vehicles with frames. Vehicles with unitized bodies seldom have this type of condition.

Frame Twist

A **frame twist** condition exists when one corner of the frame is higher than the other corners. When frame twist is present, the front or rear chassis does not sit level in relation to the road surface (Figure 14-17). Frame twist is usually caused by vehicle rollover.

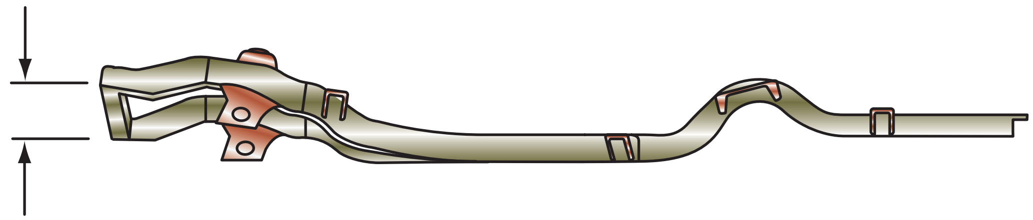


FIGURE 14-17 **Frame twist.**

Terms to Know

Axle offset
Axle sideset
Axle thrustline
Channel frame
Complete box frame
Diamond-frame condition
Directional stability
Frame buckle
Frame sag
Frame twist
Geometric vehicle centerline
High-strength steels (HSS)
Hydro-forming
Ladder frame design
Negative camber
Perimeter-type frame
Side sway
Tracking
Tubular frame
Unitized body
Wheelbase
Wheel setback

Summary

- The frame enables a vehicle to support its weight and absorb stress and torque. It also provides a main member for attachment of other components.
- In a unitized body design, all body members are load-carrying components that are welded together.
- Proper tracking and wheelbase are essential to providing directional stability.
- Each front wheel and each rear wheel must be an equal distance from the vehicle centerline to provide correct tracking.
- To provide proper wheelbase, the centers of the front and rear suspensions must be at a 90° angle to the vehicle centerline.
- Front wheel setback, rear axle offset, and rear axle sideset cause the steering to pull to one side.
- Regardless of the type of front or rear suspension system, the suspension system and the frame must position the wheels properly to provide correct tracking and wheelbase.
- Frame side sway occurs when the front suspension is forced sideways in a collision, and one front wheel is forced rearward in relation to the opposite front wheel. Side sway may also occur on the rear suspension.
- Frame sag occurs when the front or rear frame rails are bent upward in relation to the center of the frame.
- Frame buckle is accordion-shaped damage on the front or rear of the frame that causes the distance to be reduced between the cowl and front bumper or between the rear wheels and rear bumper.
- A diamond-frame condition is present when one side of the frame is driven rearward in relation to the opposite side of the frame, and the front and rear wheels on one side of vehicle are rearward in relation to the wheels on the other side.
- Frame twist occurs when one corner of the frame is bent up higher than the other frame corners.

Review Questions

Short Answer Essays

1. Explain four purposes of a vehicle frame.
2. Describe the differences between a ladder-type frame and a perimeter-type frame.
3. List six load-carrying components in a unitized body.
4. Explain the necessary wheel position to provide proper tracking.
5. Describe the necessary axle position to provide correct wheelbase.
6. Explain the effects of front wheel setback.
7. Describe the effects of rear axle offset.
8. Describe two areas in the frame where sag may occur.
9. Explain the type of collision that causes frame buckle.
10. Explain frame twist, including the type of collision that causes this problem.

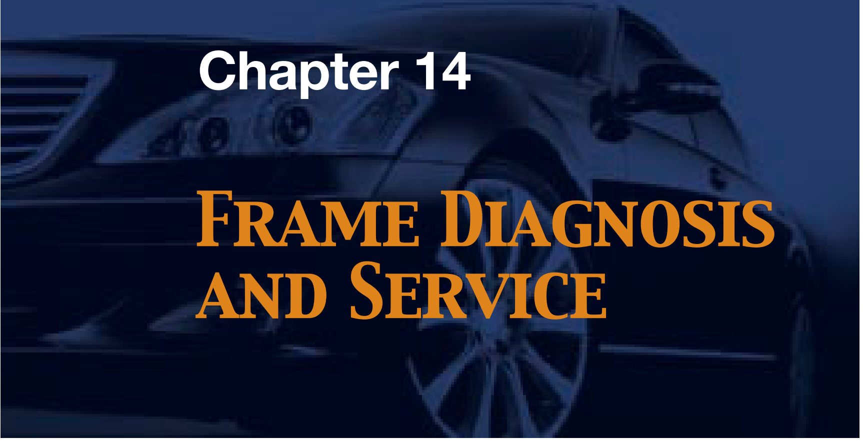
Fill-in-the-Blanks

1. The frame enables the vehicle to absorb torque from the _______________ and _______________ _______________.
2. The side rails in a ladder-type frame have very little _______________.
3. The perimeter-type frame provides a _______________ around the passenger compartment.
4. In a unitized body, each body member is a _______________ _______________ component.
5. The unitized body is designed to spread _______________ forces throughout the body.
6. Wheelbase is the distance between the front and rear wheel _______________.
7. Directional stability is the tendency of a vehicle to remain in the _______________ _______________ position when driven straight ahead on a level road.
8. Tracking refers to the _______________ relationship between the front and rear wheels.
9. When the front of the frame is buckled, the distance is reduced between the front _______________ and the _______________.
10. Frame buckle may be called frame _______________ or _______________.

Multiple Choice

1. A ladder-type frame is most commonly used on a:
   A. Rear-wheel-drive car.
   B. Front-wheel-drive car.
   C. Light-duty truck.
   D. Compact car.
2. A perimeter-type frame:
   A. Forms a border around the passenger compartment.
   B. Has frame rails that are stepped outward at the cowl area.
   C. Has a front torque box mounted behind the transmission support member.
   D. Does not have cross members welded between the frame rails.
3. All of these statements about unitized body design are true EXCEPT:
   A. The frame and body are combined as one unit.
   B. The external frame assembly is eliminated.
   C. Some body members such as quarter panels do not contribute to body strength and rigidity.
   D. Body strength is obtained by body shape and design.

4. All of these statements about vehicle tracking are true EXCEPT:
   A. The distance between the front wheels and the distance between the rear wheels must be equal.
   B. Each front wheel must be the same distance from the vehicle centerline.
   C. Each rear wheel must be the same distance from the vehicle centerline.
   D. Each front and rear wheel must be parallel to the vehicle centerline.
5. Front wheel setback occurs when one front wheel is:
   A. Tilted inward from the true vertical position.
   B. Moved rearward in relation to the opposite front wheel.
   C. Tilted rearward from the true vertical position.
   D. Inward from its original position.
6. While diagnosing rear axle offset and sideset:
   A. If the left rear wheel is moved rearward in relation to the right rear wheel, the steering pulls to the left.
   B. If the vehicle has rear leaf springs, rear axle offset may be caused by a broken spring center bolt.
   C. If rear axle sideset is present, one side of the rear axle is moved forward in relation to the opposite side or the rear axle.
   D. Rear axle sideset causes harsh ride quality and excessive vertical rear wheel oscillations.
7. All these statements about frame side sway and buckle are true EXCEPT:
   A. Frame side sway causes unequal wheelbase on the two sides of the vehicle.
   B. When a vehicle frame has a severe side sway condition, the frame is V-shaped.
   C. Frame buckle reduces the distance between the front and rear suspension systems.
   D. Frame side sway causes one corner of the vehicle to be higher compared to the other corners.
8. While diagnosing a diamond-frame condition and frame twist:
   A. A diamond-frame condition causes the wheelbase to be unequal on the two sides of the vehicle.
   B. A diamond-frame condition does not affect steering pull and directional stability.
   C. Frame twist is usually caused when a vehicle is involved in a side collision.
   D. When frame twist occurs, the front or rear chassis does not sit level in relation to the road surface.
9. On various types of vehicle frames:
   A. The load-carrying capacity is greater on a perimeter frame than on a ladder-type frame.
   B. A torque box on a perimeter-type frame absorbs most of the impact during a side collision.
   C. The frame rails are stepped inward in the cowl area to protect the engine and transmission on a perimeter-type frame.
   D. Rubber frame insulating bushings provide improved directional stability and steering characteristics.
10. In a unitized body:
   A. The partial bolt-on frames may be located at the front or rear of a vehicle with a unitized body.
   B. The rocker panels and the roof are the main load-carrying components in a unitized body.
   C. Ultra-high-strength steels are used in most unitized body components.
   D. The floor plan and the inner fender aprons do not carry any load in a unitized body.



Chapter 14

Frame Diagnosis and Service

Upon completion and review of this chapter, you should be able to:

- Take the necessary precautions to avoid frame damage.
- Diagnose the causes of frame damage.
- Follow safety precautions when measuring and welding frames.
- Visually inspect frames.
- Measure frames with a plumb bob and diagnose frame damage.
- Measure frames with a tram gauge and diagnose frame damage.
- Perform unitized body measurements with a tram gauge.
- Perform unitized body measurements with a dedicated bench system.

Improper frame or unitized body alignment may cause wheel alignment defects, rapid tire tread wear, and reduced directional stability. After collision damage, a unitized body vehicle may be repaired so it has satisfactory cosmetic appearance, but body and wheel alignment defects are still present. These defects may contribute to reduced directional stability, especially during such extreme conditions as hard cornering or severe braking. Therefore, diagnosing and correcting frame and unitized body alignment is very important to restoring vehicle safety! Body shops have mechanical or electronic body and chassis alignment equipment that can help correct improper body alignment.

BASIC TOOLS

Basic technician's tool set

Service manual

Tape measure

Chalk

Floor jack

Safety stands

Indications of Frame Damage

The most common cause of frame damage on cars and light-duty trucks is collision damage. In some cases, the collision damage may be repaired to make the cosmetic appearance of the vehicle satisfactory, but the frame damage may not always be correctable.

When driving the vehicle, some indications of frame damage are:

1. Excessive tire wear when the front suspension alignment angles are correct.
2. Steering pull when the front suspension alignment angles are correct.
3. Steering wheel not centered when driving straight ahead, but the steering wheel was centered in the shop.

Frame Diagnosis

Preventing Frame Damage

Since frame problems affect wheel alignment, technicians must be able to diagnose frame defects so they are not confused with wheel alignment problems.

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Section modulus is a measure of the frame's strength based on its height, width, thickness, and the shape of the side rails. Section modulus does not account for the type of material in the frame.

Frame flange is the horizontal part of the frame on the top and bottom of the web.

Frame web refers to the vertical side of the frame.

Yield strength is a measure of the strength of the material from which the frame is manufactured. Yield strength is the maximum load that may be placed on a material and still have the material retain its original shape. Yield strength is measured in pounds per square inch (psi) or kilopascals (kPa).

Follow these precautions to minimize frame damage:

1. Do not overload the vehicle.
2. Place the load evenly in a vehicle.
3. Do not operate the vehicle on extremely rough terrain.
4. Do not mount equipment such as a snow plow on a vehicle unless the frame is strong enough to carry the additional load and force.

Diagnosis of Frame Problems

Side Sway. The causes of frame side sway are:

1. Collision damage.
2. Fire damage.
3. Use of equipment on the vehicle for which the frame was not designed.

Sag. The causes of frame sag are:

1. Vehicle loads that exceed the load-carrying capacity of the frame.
2. Uneven load distribution.
3. Sudden changes in **section modulus**.
4. Holes drilled in the **frame flange**.
5. Too many holes drilled in the **frame web**.
6. Holes drilled too close together in the frame web.
7. Welds on the frame flange.
8. Cutting holes in the frame with a cutting torch.
9. Cutting notches in the frame rails.
10. A fire involving the vehicle.
11. Collision damage.
12. The use of equipment for which the frame was not designed.

Buckle. The causes of frame buckle are:

1. Collision damage.
2. Using equipment such as a snow plow when the frame was not designed for this type of service.
3. A fire involving the vehicle.

Diamond-Shaped. Diamond-shaped frame damage may be caused by:

1. Collision damage.
2. Towing another vehicle with a chain attached to one corner of the frame.
3. Being towed by another vehicle with a chain attached to one corner of the vehicle frame.

Twist. Frame twist may be caused by:

1. An accident or collision, especially one involving a rollover.
2. Operating the vehicle on extremely rough terrain.

Checking Frame Alignment

Safety Concerns

While servicing vehicle frames, always wear the proper safety clothing and safety items for the job being performed. This includes proper work clothing, safety goggles, ear protection, respirator, proper gloves, welding shield, and safety shoes (Figure 14-1).

If arc welding is necessary on a vehicle frame, follow these precautions:

1. Remove the negative battery cable before welding (Figure 14-2).
2. Remove the fuel tank before welding (Figure 14-3).
3. Protect the interior and exterior of the vehicle as necessary (Figure 14-4).

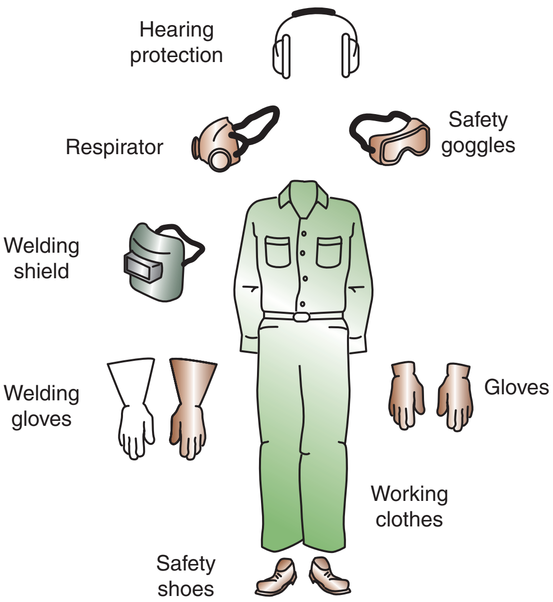


FIGURE 14-1 **Safety items for frame service.**


FIGURE 14-2 **Remove the negative battery cable before arc welding on a vehicle.**

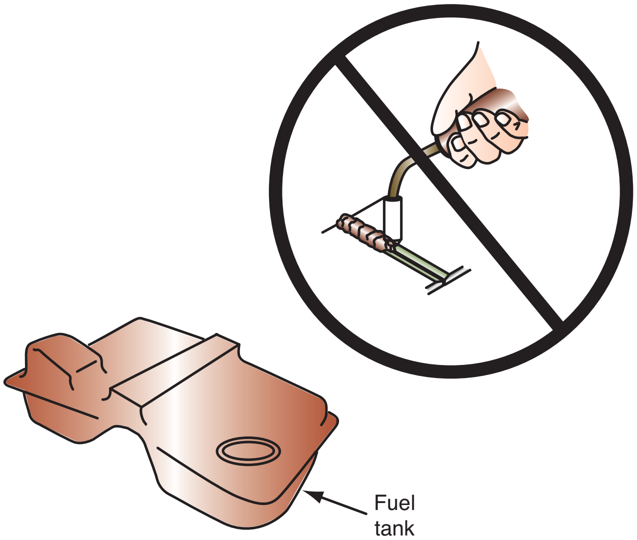


FIGURE 14-3 **Remove the fuel tank before arc welding on a vehicle.**


FIGURE 14-4 **Protect the interior and exterior of the vehicle while arc welding.**

Visual Inspection

Prior to frame measurement, the frame and suspension should be visually inspected. Check for wrinkles on the upper flange of the frame, which indicate a sag problem. Visually inspect the lower flange for wrinkles, which are definite evidence of buckle. Since suspension or axle problems may appear as frame problems, the suspension components should be inspected for wear and damage. For example, an offset rear axle may appear as a diamond-shaped frame. Check all suspension mounting bushings and inspect leaf-spring shackles and center bolts.

The frame should be inspected for cracks, bends, and severe corrosion. Minor frame bends are not visible, but severe bends may be visible. Straight cracks may occur at the edge of the frame flange, and **sunburst cracks** may radiate from a hole in the frame web or cross member (Figure 14-5).

Sunburst cracks radiate outward from a holein a frame web or cross member.

CAUTION: Always follow the vehicle manufacturer's recommendations in the service manual regarding welding or reinforcing the frame, or mounting additional equipment on the frame. If these recommendations are not followed, the frame may be weakened and damaged.

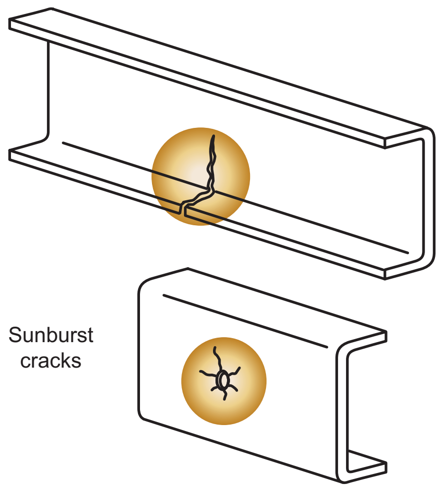


FIGURE 14-5 **Straight cracks may occur in the frame flange; sunburst cracks may radiate from a hole in the frame web or cross member.**

SERVICE TIP: If the frame is cracked, frame alignment is often necessary.

Frame Welding

Follow these steps for a typical frame welding procedure:

1. Remove any components that would interfere with the weld or be damaged by heat.
2. Find the extreme end of the crack and drill a 0.25 in. (6-mm) hole at this point.
3. V-grind the entire length of the crack from the starting point to the drilled hole.
4. The bottom of the crack should be opened 0.062 in. (2 mm) to allow proper weld penetration. A hacksaw blade may be used to open the crack.
5. Arc weld with the proper electrode and welding procedure.

Frame Measurement, Plumb Bob Method

Photo Sequence 25 shows a typical procedure for performing frame measurement using the plumb bob method.

Locating the Frame Centerline. Some vehicle manufacturers recommend measuring the frame with the **plumb bob** method.

A **plumb bob** is a weight with a sharp, tapered point that is suspended and centered on a string. Plumbers use this tool for locating pipe openings directly above each other in the tops and bottoms of partitions.

Follow these steps to complete a plumb bob measurement for frame damage:

1. Place the vehicle on a level area of the shop floor and use a floor jack to raise the front and rear suspension off the floor. Support the chassis on safety stands at the manufacturer's recommended locations.
2. Suspend a plumb bob at locations 1, 2, 11, and 12 on the inside of the frame web, and allow the plumb bob to almost touch the floor surface (Figure 14-6). Points 1 and 2 are at the centerline of the slotted hole in each front bumper bracket, and points 11 and 12 are on the inside of the rear frame web. Mark these plumb bob locations on the floor with chalk.
3. Use a plumb bob to transfer points 3 through 10 from the frame to chalk marks on the floor.
4. Raise the vehicle with the floor jack, remove the safety stands, and lower the vehicle onto the floor. Move the vehicle away from the chalk-marked area.
5. Measure the distance between points 1 and 2 with a tape measure, and chalk mark the exact halfway point in this distance. This mark is the frame centerline at the front.
6. Measure the distance between points 11 and 12, and chalk mark the exact center of this measurement. This chalk mark is the frame centerline at the rear.
7. Draw a straight chalk line from the centerline at the front of the frame to the centerline at the rear of the frame. This chalk line is the complete centerline of the frame.

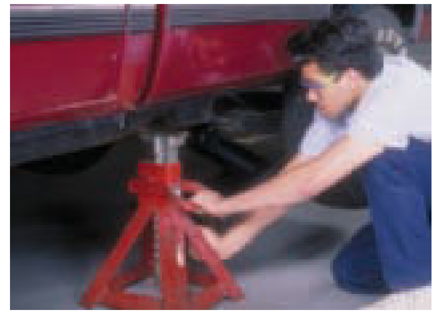
SPECIAL TOOLS
Plumb bob

PHOTO SEQUENCE 25

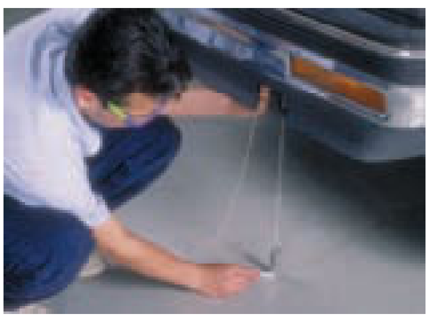
Typical Procedure for Performing Frame Measurement, Plumb Bob Method

P25-1 **Park the vehicle on a level area of the shop floor.**

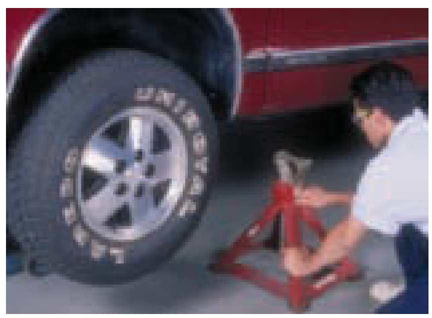
P25-2 **Raise the front suspension with a floor jack and lower the chassis onto safety stands positioned at the manufacturer's recommended lifting points.**



P25-3 **Raise the rear suspension with a floor jack and lower the chassis onto safety stands positioned at the manufacturer's recommended lifting points.**



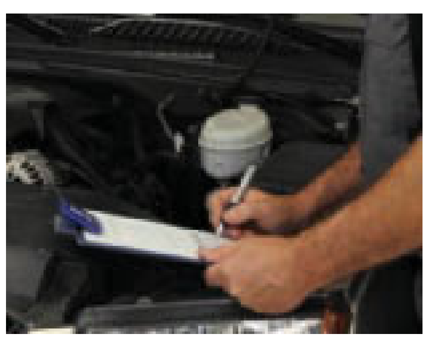
P25-4 **Suspend a plumb bob at the manufacturer's recommended frame measurement locations and place a chalk mark on the floor directly under the plumb bob.**



P25-5 **Use a floor jack to lift the vehicle, remove the safety stands, and lower the vehicle.**

P25-6 **Drive the vehicle away from the chalk-marked area.**

P25-7 **Use a tape measure to measure the vehicle's frame measurements between the chalk marks on the floor.**



P25-8 **Compare the frame measurements obtained with the vehicle manufacturer's specifications in the service manual.**

SERVICE TIP: The points on the left and right frame webs must be at the same location on each web for accurate measurements.

SERVICE TIP: When using a tape measure, avoid twists and bends in the tape to provide accurate readings.

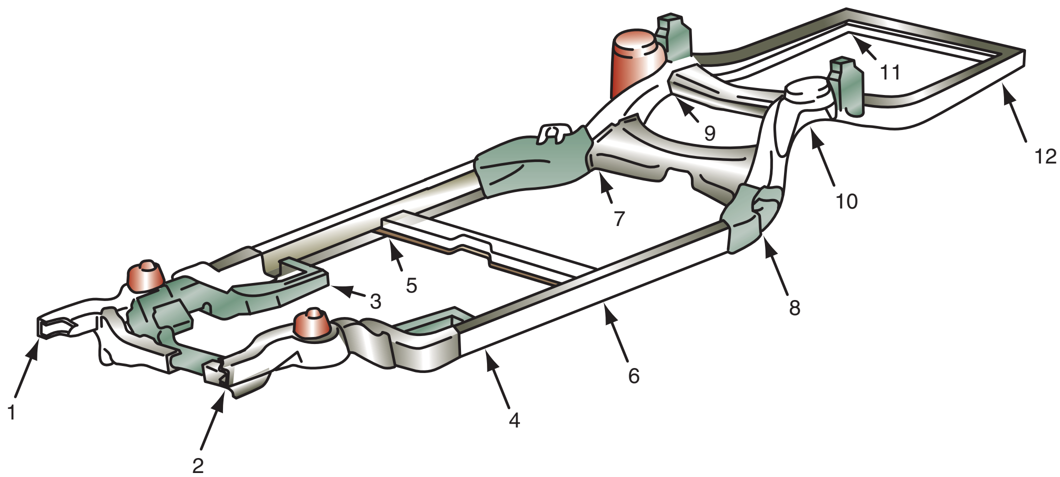


FIGURE 14-6 **Suspend a plumb bob at the locations shown on the frame and mark these locations on the floor with chalk.**

Horizontal Frame Measurements

The procedure used for horizontal frame measurements follows:

1. Measure the distance from the frame centerline to points 3 through 10. Each pair of these points should be equal within 0.125 in. (3 mm). For example, the distance from point 5 to the centerline should be equal to the distance from point 6 to the centerline.
2. Measure diagonally from point 1 to 6 and point 2 to 5. These distances should be equal or within the manufacturer's specified tolerance. Place a straight chalk mark from points 1 to 6 and points 2 to 5. These diagonal lines should cross each other at the frame centerline.
3. Repeat step 2 at all the other diagonal frame measurements, such as points 3 to 10, 4 to 9, 5 to 12, and 6 to 11. All these diagonal measurements should be equal or within the vehicle manufacturer's specified tolerance. Each pair of diagonal lines must cross each other at the vehicle centerline (Figure 14-7).

When such frame problems as side sway, buckle, or a diamond-shaped condition are present, some of the horizontal frame measurements are not within specifications, and some of the diagonal chalk lines do not cross at the frame centerline, depending on the location of the damaged area.

Frame Measurement, Tram Gauge Method

A **tram gauge** is a long, straight bar with two adjustable pointers that is used for frame measurements. A tram gauge may be called a tracking or track gauge.

A **tram gauge** is a long, straight bar with two adjustable pointers. The distance between the pointers is adjustable, and the height of the pointers is also adjustable (Figure 14-8).

The horizontal frame measurements may be completed with a tram gauge, rather than using the plumb bob method. When measuring a frame, horizontal measurements are

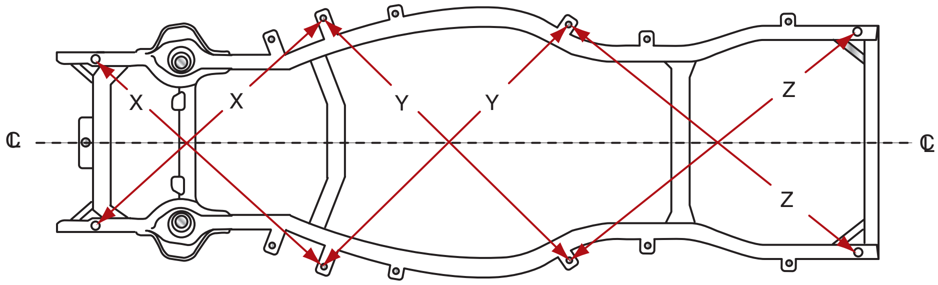


FIGURE 14-7 **Each pair of diagonal measurement lines on the frame must cross each other at the frame centerline.**

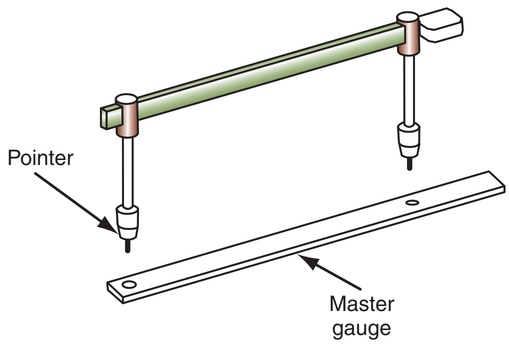


FIGURE 14-8 **Tram gauge for frame measurements.**

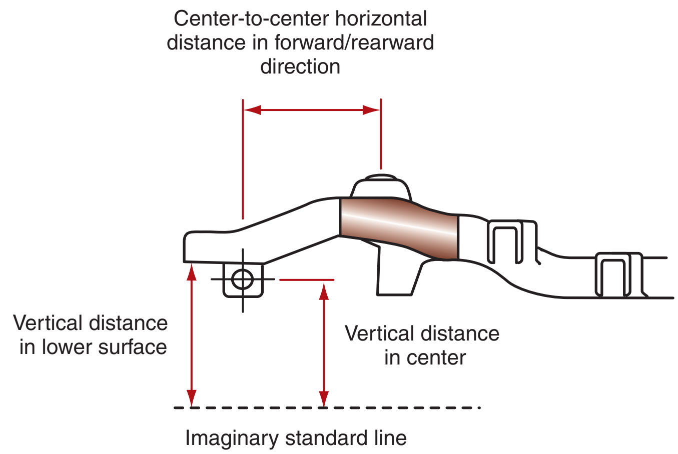


FIGURE 14-9 **Horizontal and vertical frame measurements.**

completed straight across the frame and diagonally forward and rearward on the frame, as discussed previously.

Vertical measurements from specific locations on the frame to an imaginary standard line are also necessary to detect such conditions as frame sag and twist (Figure 14-9). This imaginary horizontal line used for vertical frame measurements is called the **datum line.**

An imaginary horizontal line parallel to the frame is used for vertical frame measurements. This line is called the **datum line**.

When vertical frame measurements are completed with the tram gauge, the gauge pointers must be set at the manufacturer's specified distance for each frame location (Figure 14-11). With the tram gauge pointers set at the specified height and the gauge properly installed across the frame in the recommended frame openings, the tram gauge should be level if the vertical frame measurements are within specifications. If the frame is twisted, the tram gauge is not level when adjusted to specifications and installed in the twisted area.

To measure frame sag, three tram gauges may be installed at various locations for vertical frame measurement. When viewed from the front or the rear, the tram gauges must be level with each other. If the tram gauge near the center of the frame is lower than the tram gauges at the front and rear of the frame, the frame is sagged.

SERVICE TIP: When the tram gauge is installed on the frame, be sure the pointers are seated properly in the frame openings (Figure 14-10).

Frame Straightening

Frame straightening is usually done with special hydraulically operated bending equipment. This equipment must be operated according to the equipment manufacturer's recommended procedures. Since frame straightening is usually done by experienced body technicians, we will not discuss this service in detail. All safety precautions must be observed while operating

SPECIAL TOOLS
Tram gauge

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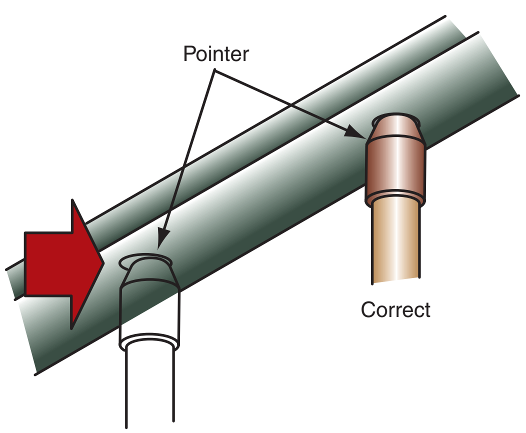

FIGURE 14-10 **Correct and incorrect tram gauge pointer seating in the frame openings.**

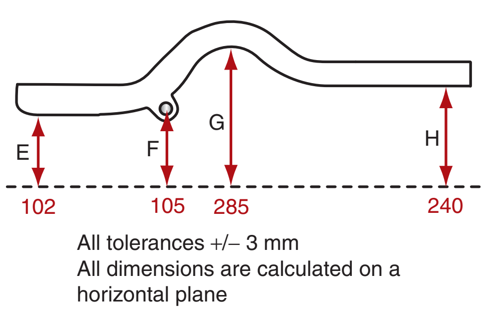

FIGURE 14-11 **Tram gauge setting and locations for vertical frame measurements, rear subframe.**

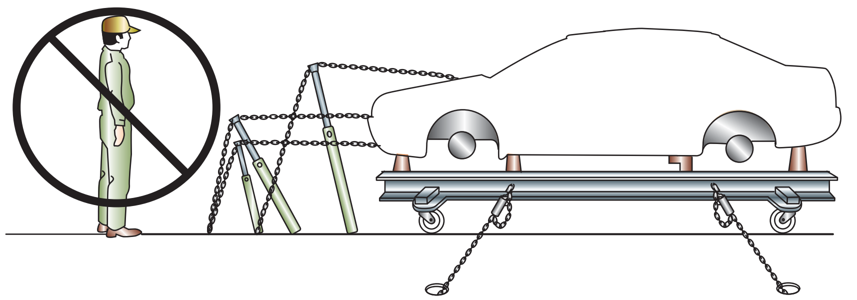

FIGURE 14-12 **Do not stand in front of pulling equipment while it is in operation.**

frame-straightening equipment. Never stand in front of pulling equipment when it is in operation (Figure 14-12).

Measuring Unitized Body Alignment

Tram Gauge

On unitized bodies, a tram gauge may be used to perform such measurements as the upper strut towers (Figure 14-13) and the front cross member (Figure 14-14).

If the underhood body measurements such as the strut tower measurements are not within specifications, the strut towers may not be in the original position. Collision damage may cause the strut towers to move out of the original position. If the strut towers are out of position, the front alignment angles are incorrect. Photo Sequence 26 illustrates the underhood body measurements.

Because the lower control arms are attached to the cross member or cradle and also to the lower end of the steering knuckle, if the crossmember is moved from the original intended position, front wheel alignment is adversely affected (Figure 14-15). Improper cross member position may be caused by loose, worn cross member mounts or a bent cross member. Improper front wheel alignment may result in excessive front tire tread wear, steering pull, steering wander, and reduced directional stability. When removing a front cross member, always mark the cradle in relation to the chassis so it can be re-installed in the original position.

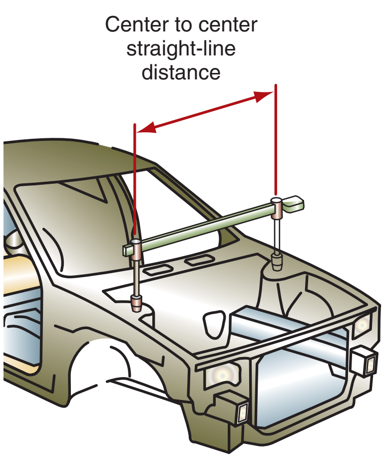

FIGURE 14-13 **Performing an upper strut tower measurement with a tram gauge on a unitized body vehicle.**

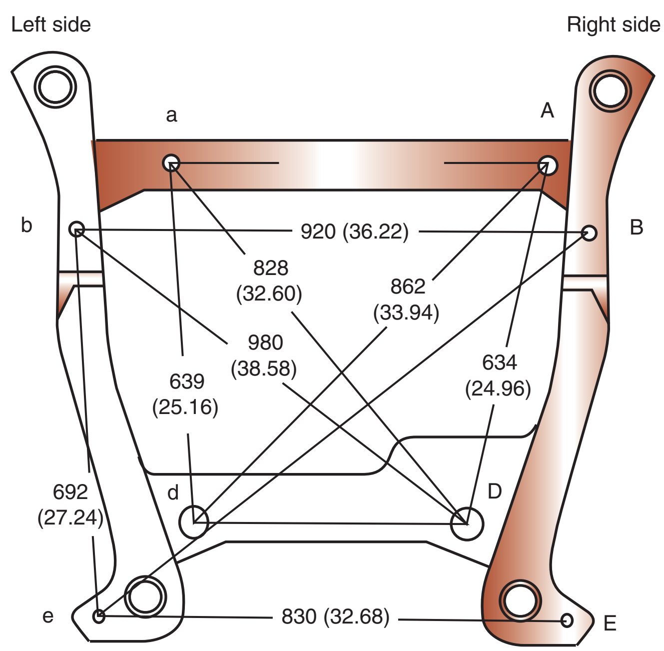

FIGURE 14-14 **Tram gauge measurements on the front cross member of a unitized body vehicle.**

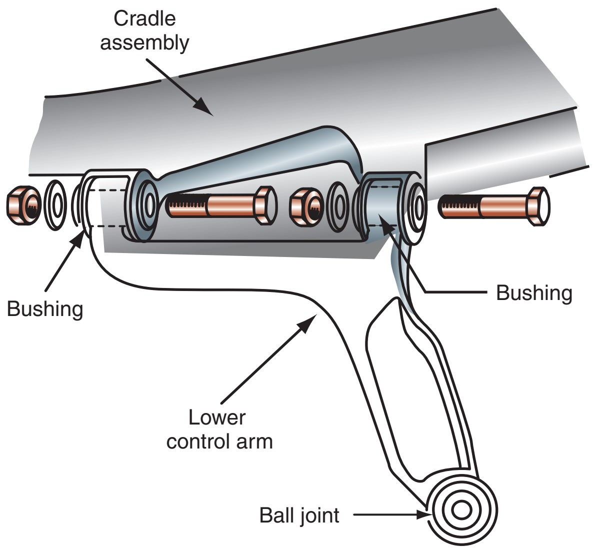

FIGURE 14-15 **Lower control arm-to-cradle attachment.**

The engine and transaxle mounts are also connected to the front cross member. Therefore, a bent cross member or improperly positioned cross member mounts may cause improper engine and transaxle position, which results in vibration problems. Therefore, when diagnosing and correcting engine, drive axle, or transaxle vibration problems, always be sure the front cross member, engine mounts, transaxle mounts, and cross member mounts are in satisfactory condition. The tram gauge may be used to perform vertical measurements on the front and rear subframes on a unitized body vehicle.

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Bench

A **dedicated bench system** is necessary to check many unitized body measurements after medium or heavy collision damage. The dedicated bench system has three main parts: the bench, transverse beams, and the dedicated fixtures. When used together, this equipment will perform many undercar unitized body measurements, including length, width, and height at the same time. The bench contains strong steel beams mounted on heavy casters (Figure 14-16). The top of the bench acts as a datum line.

SPECIAL TOOLS
Dedicated bench system

Transverse Beams

The transverse beams are mounted perpendicular to the bench. There are a variety of holes in the bench for proper transverse beam attachment (Figure 14-17). Various holes in the transverse beams provide the correct dedicated fixture positions.

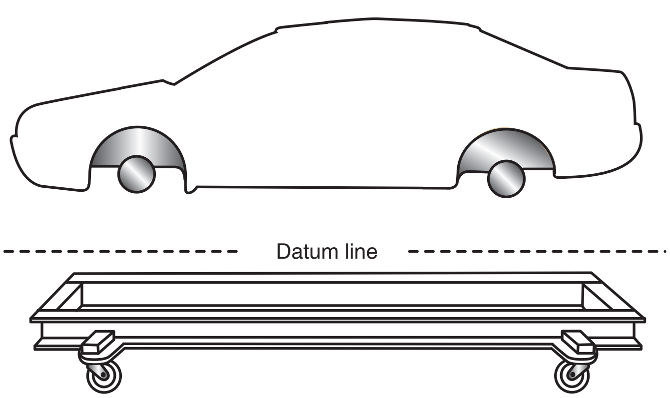

FIGURE 14-16 **Bench from a dedicated bench system.**

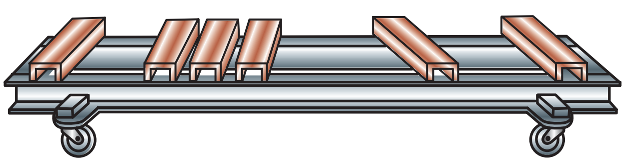

FIGURE 14-17 **Transverse beams placed on the bench.**

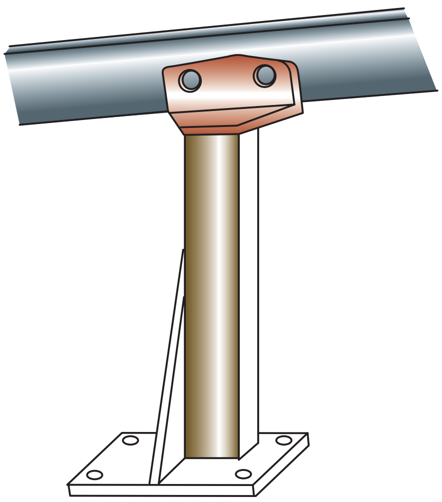

FIGURE 14-18 **Dedicated fixtures are specific to the body style being measured.**

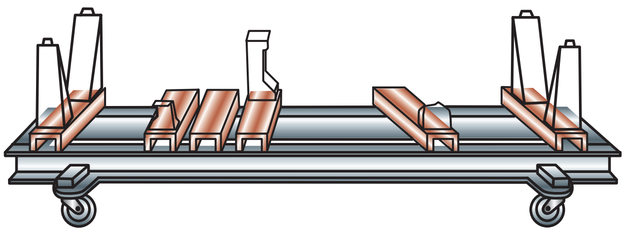

FIGURE 14-19 **Dedicated fixtures are bolted to the transverse beams in specific locations depending on the body style.**

Dedicated Fixtures

The dedicated fixtures are specific to the body style being measured (Figure 14-18). These fixtures are bolted to the transverse beams, and the holes in the upper end of the fixtures must be aligned with specific body openings (Figure 14-19).

The unitized body must be straightened until the holes in the dedicated fixtures and the body openings are aligned. If the holes in the unitized body are behind and above the dedicated fixture openings, the unitized body must be pulled forward and downward in that area (Figure 14-20).

Universal benches are now available with computer measuring systems. Measuring a unitized body with a bench system and straightening these bodies with special body pulling equipment is usually done in an autobody shop rather than an automotive repair shop.

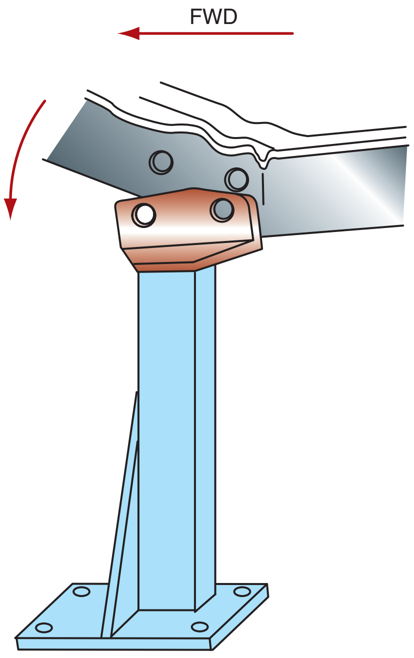

FIGURE 14-20 **When holes in the body are behind and above the openings in the dedicated fixture, the unitized body must be pulled forward and downward in that area.**

Electronic body and chassis alignment equipment using laser beam technology is used in many body shops during collision repair.

Unitized Body Straightening

WARNING: Always follow all the recommended precautions and procedures in the vehicle manufacturer's service manual and in the equipment manufacturer's operator's manual when straightening a unitized body. Failure to follow these precautions and procedures may result in severe personal injury and property damage.

Since unitized body straightening is usually performed by experienced body technicians, our discussion is brief on this subject. During the straightening process on a unitized body, the body is securely bolted to the dedicated bench at all the possible locations except those where misalignment is present. The dedicated bench is securely chained to special holding fixtures in the shop floor. Hydraulically operated pulling equipment is then attached securely to the unitized body to pull the body in the intended direction. **Single-pull** equipment pulls only one location at a time (Figure 14-21), and **multipull** equipment pulls in several locations at the same time (Figure 14-22). The unitized body is pulled until the holes in the body are aligned with the holes in the dedicated fixtures.

Single-pull body straightening equipment will pull only one location at a time.

Multipull body straightening equipment will pull in several locations at the same time.

CUSTOMER CARE: Always treat customers and their vehicles with respect! Remember that all customers deserve to be treated with respect regardless of their appearance, the mood they are in, or the type of vehicle they drive. When customers notice that you always respect them and their vehicle, they will have a better impres sion of your business, and they are likely to return to your shop for all their service requirements.

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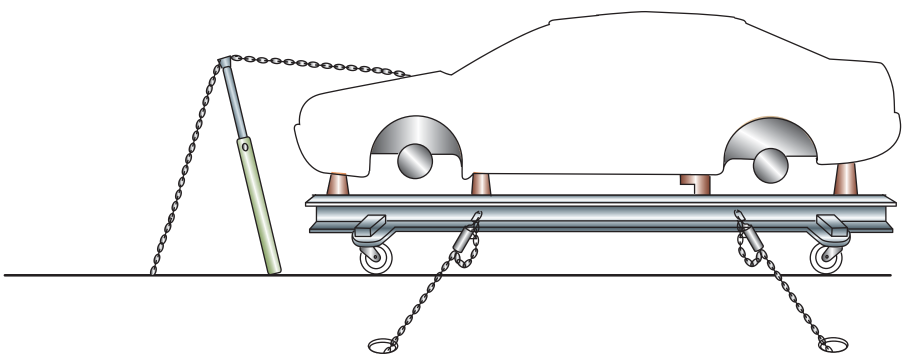


FIGURE 14-21 **Single-pull unitized body straightening system.**

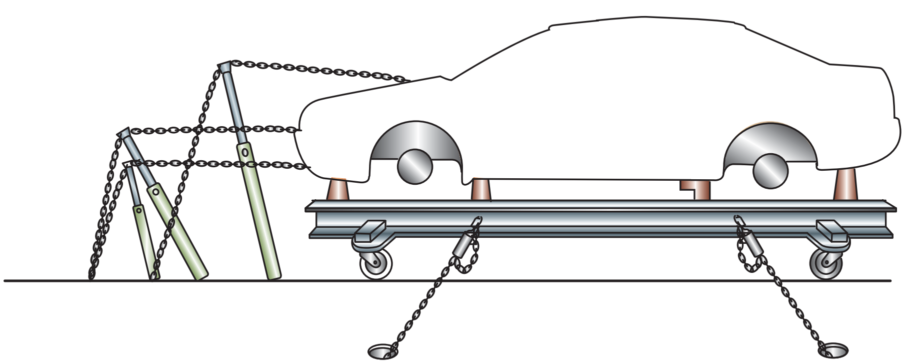
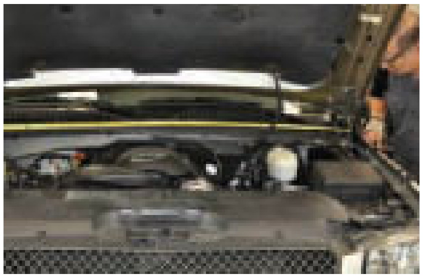


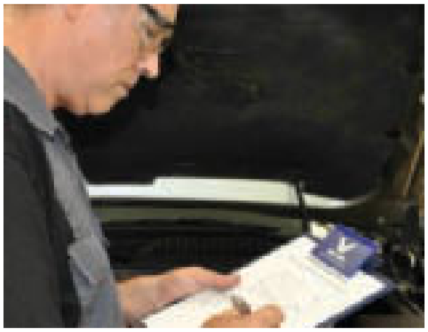
FIGURE 14-22 **Multipull unitized body straightening system.**

PHOTO SEQUENCE 26

PERFORMING UNDERHOOD MEASUREMENTS

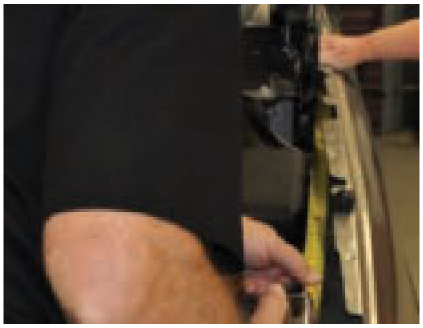


P26-1 **Perform horizontal underhood measurements.**

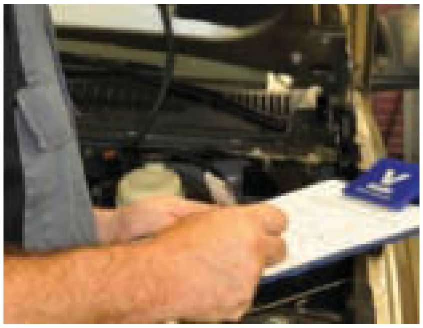


P26-2 **Record the horizontal underhood measurements.**

P26-3 **Compare horizontal underhood measurements to specifications and identify measurements that are not equal to the specifications (Figure 14-23).**

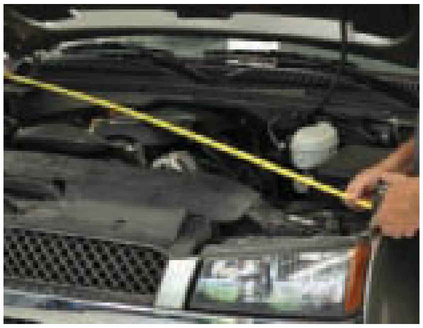


P26-4 **Perform point-to-point underhood measurements.**



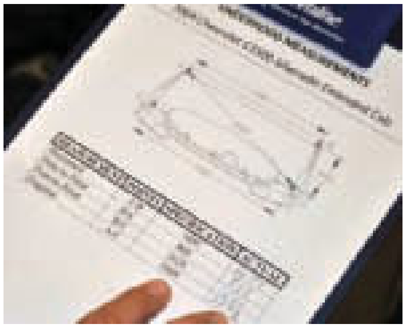
P26-5 **Record the point-to-point underhood measurements.**

P26-6 **Compare point-to-point underhood measurements to specifications and identify measurements that are not equal to the specifications (Figure 14-24).**



P26-7 **Perform diagonal underhood measurements.**

P26-8 **Record the diagonal underhood measurements.**



P26-9 **Compare diagonal underhood measurements to specifications and identify measurements that are not equal to the specifications (Figure 14-25).**

TABLE 14-1 **DIAGNOSING FRAME AND BODY DAMAGE**

Problem	Symptoms	Possible Causes
Excessive front tire tread wear	Front tire tread wear with correct front suspension alignment angles	Frame, front cradle damage
Steering pull when driving straight ahead	Steering pull with correct front and rear alignment angles	Frame, front cradle damage
Steering wheel not centered when driving straight ahead	Steering wheel centered in the shop, but it is not centered when driving straight ahead	Frame, front cradle damage
Improper strut tower position	Incorrect front suspension alignment angles, steering pull, tire tread wear	Collision damage
Frame buckle	Wrinkles in frame flanges	Collision damage, vehicle abuse
Improper cradle measurements or position	Incorrect front suspension alignment angles, steering pull, tire tread wear	Collision damage, worn or improperly positioned cradle mounts

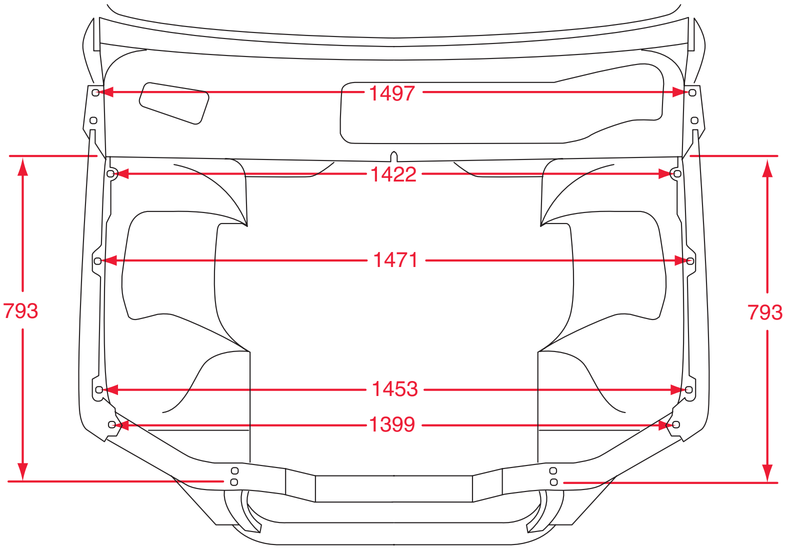


FIGURE 14-23 **Performing horizontal underhood measurements.**

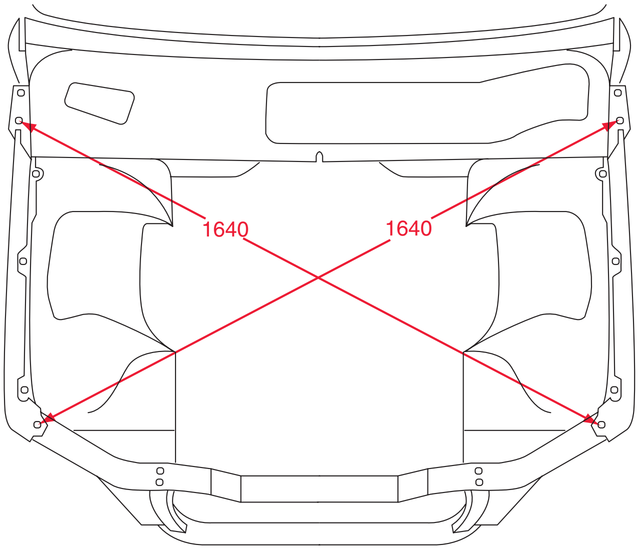


FIGURE 14-24 **Performing point to point underhood measurements.**

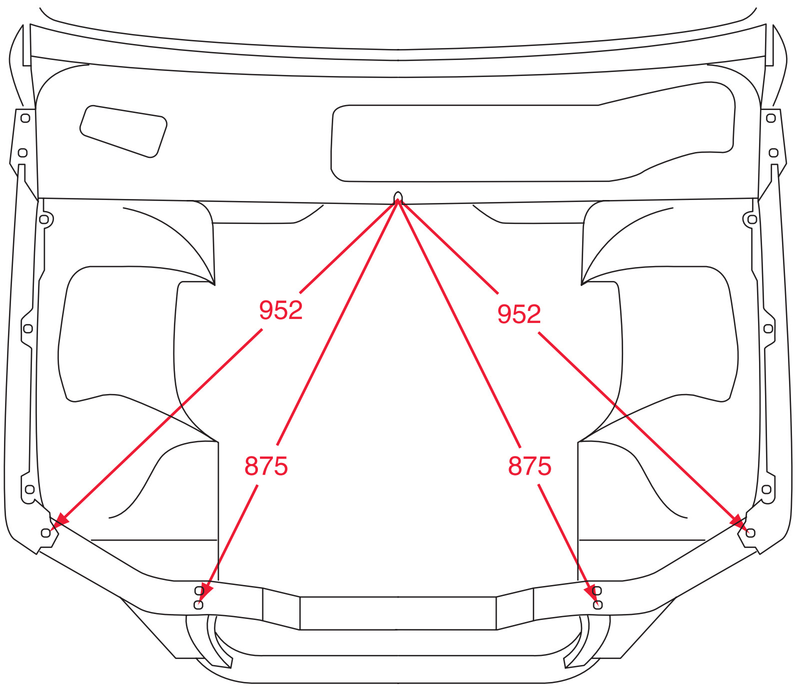


FIGURE 14-25 **Performing diagonal underhood measurements.**

CASE STUDY

A customer complained about a vibration problem on an Chryster Concorde with front-wheel drive. Further questioning of the customer revealed that the vibration occurred when accelerating and decelerating at 40 to 60 mph (64 to 96 km/h). During a road test, the technician found the customer's description of the problem was accurate. The car did have a vibration problem at the speed indicated by the customer. While road-testing the car, the technician thought about the causes of this problem and decided the most likely cause of the vibration would be inner front drive axle joints. The technician informed the customer that a drive axle joint inspection was necessary.

The technician raised the vehicle on a hoist and checked the front drive axle joints. He was surprised to discover the inner and outer joints were all in good condition with no cracked boots or looseness. An inspection of the engine cradle indicated the crosspiece at the rear of the cradle was severely damaged near the left side of the cradle. It appeared this crosspiece may have struck an object such as a rock during off-road driving. A check of the cradle mounts indicated the cradle openings were jammed into the rubber mounts on the left side of the cradle. The rubber mounts were bulged at the rear of the cradle openings, indicating the left side of the cradle was driven rearward.

The technician informed the customer that cradle removal, measurement, and possible replacement was necessary. After the customer approved this service operation, the technician removed the cradle and measured it with a tram gauge. The diagonal measurements on the cradle were not within the manufacturer's specifications. Since the cradle was severely distorted, a replacement cradle was installed, and all damaged cradle mounting bushings were replaced. A road test indicated the vibration problem was corrected.

Terms to Know

Datum line
Dedicated bench system
Frame flange
Frame web
Multipull
Plumb bob
Section modulus
Single-pull
Sunburst cracks
Tram gauge

ASE-Style Review Questions

1. While discussing frame sag:

   Technician A says frame sag may be caused by holes drilled in the frame flange.

   Technician B says frame sag may be caused by holes drilled too close together in the frame web.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While discussing frame side sway:

   Technician A says frame side sway may be caused by uneven load distribution.

   Technician B says frame side sway may result from too many holes drilled in the frame web.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. While discussing a diamond-shaped frame condition:

   Technician A says this condition may be caused when the vehicle is involved in a fire.

   Technician B says this condition may be caused by towing another vehicle with the chain attached to one corner of the frame.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. When discussing the plumb bob method of frame measurement:

   Technician A says the distance from the frame centerline to the same point on each side of the frame should be equal.

   Technician B says diagonal frame measurement lines on each side of the vehicle should cross each other at the frame centerline.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

5. When discussing vertical frame measurements:

   Technician A says the datum line is an imaginary horizontal line parallel to the vehicle frame that is used for vertical frame measurements.

   Technician B says if three tram gauges are properly adjusted and installed at specified locations on the frame, these gauges should be level with each other.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

6. All of these statements about frame problems are true EXCEPT:

   A. Frame sag may be caused by overloading the vehicle.
   B. Frame sag may be caused by the use of equipment for which the frame was not designed.
   C. Frame buckle may be caused by using a snow plow on the front of the vehicle.
   D. A diamond-shaped frame may be caused by operating the vehicle on extremely rough terrain.

7. While diagnosing and inspecting vehicle frames:

   A. Wrinkles on the lower frame flange indicate frame buckle.
   B. Fire damage may cause frame twist.
   C. Unequal vehicle load distribution may cause frame side sway.
   D. Frame twist may be caused by cutting notches in the frame flanges.

8. When welding a vehicle frame crack:

   A. A 0.25 in. hole should be drilled in the center of the crack.
   B. The crack should be V-ground at both ends of the crack.
   C. Disconnect the negative battery cable before welding the crack.
   D. Use a cutting torch to open the crack for proper weld penetration.

9. While performing unitized body measurements:

   A. A dedicated bench system performs measurements on upper strut towers.
   B. Fixtures on a dedicated bench system are specific for the vehicle body being straightened.
   C. The fixtures are bolted to the bench in a dedicated bench system.
   D. The transverse beams on a dedicated bench system are specific for the body being straightened.

10. While inspecting and measuring a front cradle on a front-wheel-drive car:

    A. Front wheel alignment angles may be changed by a bent front cradle.
    B. Engine mounting position is not affected by a bent front cradle.
    C. A bent front cradle has no effect on front drive axle vibration.
    D. A bent front cradle may cause premature front wheel bearing failure.

ASE Challenge Questions

1. When making horizontal frame measurements to determine if the frame or unibody is straight, all of the measurements should be made with reference to which one of the following?
   A. Vertical C. Horizontal
   B. Centerline D. Body bushings

2. A bent front cross member affects all of the following alignments EXCEPT:
   A. Centerline. C. Axle.
   B. Suspension. D. Engine.

3. While discussing frame damage:
   Technician A says a possible indication of frame damage is an uncentered steering wheel when driving straight ahead.
   Technician B says suspension alignment may be impossible if the frame is bent.Who is correct ?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. Which of the following makes this statement true? Measurement points of a frame or unibody using a tram gauge are:
   A. Seam notches.
   B. Calculated by computer.
   C. Based on a vertical datum plane.
   D. Manufacturer's-specified frame openings.

5. Referring to Figure 14-14:
   Technician A says the measurement between "e" and "b" should be no more than ±1.0 in. different from the measurement between "E" and "B."
   Technician B says frame damage problems, such as buckling, can be determined if the measurements between points "e" and "E" are more than ±0.25 in. different than between "b" and "B."
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

JOB SHEET 44

Name ______________________________ **Date** ____________________

FRAME MEASUREMENT, PLUMB BOB METHOD

Upon completion of this job sheet, you should be able to perform frame measurements with a plumb bob.

Tools and Materials

Floor jack	Plumb bob
Safety stands	Chalk

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ______________________________

VIN ______________________________ Engine type and size ________________________

Procedure

Task Completed

1. Place the vehicle on a level area of the shop floor and use a floor jack to raise the front and rear suspension off the floor. Support the chassis on safety stands at the manufacturer's recommended locations.

   Is the vehicle chassis supported securely on safety stands? ☐ Yes ☐ No

   Instructor check ____

2. Locate the frame measurement locations in the vehicle manufacturer's service manual. ☐

3. Suspend a plumb bob at each frame measurement location and place a chalk mark on the floor directly below the tip of the plumb bob.

   Are all frame measurement locations chalk marked on the shop floor? ☐ Yes ☐ No

   Instructor check ____

4. Raise the vehicle with the floor jack, remove the safety stands, and lower the vehicle onto the floor. Move the vehicle away from the chalk-marked area. ☐

5. Measure the distance between the two chalk marks directly across from each other at the front of frame, and chalk mark the exact halfway point in this distance. This mark is the frame centerline at the front.

   Distance between the two chalk marks directly across from each other at the front of the frame ________________________

   Midpoint in the distance between the two chalk marks directly across from each other at the front of the frame ________________________

6. Measure the distance between the two chalk marks directly across from each other at the rear of the frame, and chalk mark the exact halfway point of this distance. This mark is the frame centerline at the rear.

SERVICE TIP: The measurement points on the left and right frame webs must be at the same location on each web to obtain accurate measurements.

Distance between the two chalk marks directly across from each other at the rear of the frame ______________________

Midpoint of the distance between the two chalk marks directly across from each other at the rear of the frame ______________________

7. Draw a straight chalk line from the centerline at the front of the frame to the centerline at the rear of the frame. This chalk line is the complete centerline of the frame.

Is the vehicle centerline chalk marked on shop floor? ☐ Yes ☐ No

Instructor check ____

SERVICE TIP: When using a tape measure, avoid twists and bends in the tape to provide accurate readings.

8. Use a tape measure to measure the distance from the frame centerline to all frame measurement points directly opposite each other. Each pair of these points should be equal within 0.125 in. (3 mm).

Frame measurements between specified measurement locations that are directly opposite each other and the vehicle centerline, starting at the front of the frame:

A. left side __________ right side __________ difference __________

B. left side __________ right side __________ difference __________

C. left side __________ right side __________ difference __________

D. left side __________ right side __________ difference __________

Necessary frame repairs:

____

____

____

9. Use a tape measure to complete all diagonal frame measurements at the vehicle manufacturer's recommended locations. These distances should be equal or within the manufacturer's specified tolerances.

Distances between diagonal frame measurement points:

Diagonal frame measurements at the front of the frame:

diagonal A __________ diagonal B __________
difference between diagonal A and B __________

Diagonal frame measurements at the center of the frame:

diagonal C __________ diagonal D __________
difference between diagonal C and D __________

Diagonal frame measurements at the rear of the frame:

diagonal E __________ diagonal F __________
difference between diagonal E and F __________

Necessary frame service:

____

____

____

10. Use a long, straight steel bar to place a straight chalk mark between all frame diagonal measurement locations. These diagonal lines should cross each other at the frame centerline.

    If all diagonal lines do not cross the frame centerline at the same location, state the required frame repairs.

    ____

    ____

Instructor's Response ____

____

____

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Name ______________________________ Date ____________________

Inspect and Measure Front Cradle

Upon completion of this job sheet, you should be able to inspect and measure front cradles.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task: check front and/or rear cradle (sub frame alignment; determine necessary action.

Tools and Materials

Tram gauge

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ______________________________

VIN ______________________________ Engine type and size ________________________

Procedure

Task Completed

1. Raise the vehicle on a lift using the vehicle manufacturer's specified lifting points. ☐
2. Inspect front cradle mounts for looseness, damage, oil soaking, wear, and deterioration.

   Cradle mount condition: right front ___________ right rear ___________

   left front ___________ left rear ___________
3. Inspect front cradle for visible bends and damage.
   Front cradle condition indicated in visible inspection:

   ____

   ____

   ____
4. Inspect front cradle alignment.

   Is the front cradle aligning hole(s) properly aligned with the matching hole in the chassis? ☐ Yes ☐ No

   Recommended cradle service:

   ____

   ____

   ____
5. Use a tram gauge to complete all measurements across the width of the cradle starting at the front of the cradle.

   Width measurement A ___________

   Specified width measurement A ___________

   Width measurement B ___________

   Specified width measurement B ___________

Width measurement C ___________

Specified width measurement C ___________

Width measurement D ___________

Specified width measurement D ___________

Width measurement E ___________

Specified width measurement E ___________

Necessary cradle service:

____

____

6. Use a tram gauge to complete all front-to-rear measurements on the cradle, starting on the left side of the cradle.

   Front-to-rear measurement A ___________

   Specified front-to-rear measurement A ___________

   Front-to-rear measurement B ___________

   Specified front-to-rear measurement B ___________

   Front-to-rear measurement C ___________

   Specified front-to-rear measurement C ___________

   Front-to-rear measurement D ___________

   Specified front-to-rear measurement D ___________

   Necessary cradle service:

   ____

   ____

7. Use a tram gauge to complete all diagonal cradle measurements, starting at the left side of the cradle.

   Diagonal measurement A ___________

   Specified diagonal measurement A ___________

   Diagonal measurement B ___________

   Specified diagonal measurement B ___________

   Diagonal measurement C ___________

   Specified diagonal measurement C ___________

   Diagonal measurement D ___________

   Specified diagonal measurement D ___________

   Necessary cradle service:

   ____

   ____

Instructor's Response ____

____

____

Name ________________________________ Date ____________________

Inspect and Weld Vehicle Frame

Upon completion of this job sheet, you should be able to inspect and weld a vehicle frame.

CAUTION: Always wear eye protection while working in the shop, and use the specified eye protection while arc welding to prevent eye injury.

Tools and Materials

Hand pump	Welding hammer
Arc welder	Welding rods

Describe the Vehicle Being Worked On:

Year ________ Make ________________ Model ________________________

VIN ________________________ Engine type and size ____________________

Procedure

Task Completed

1. Raise the vehicle on a lift using the vehicle manufacturer's specified lifting points. ☐
2. Read the instructions for disconnecting the negative battery cable in the vehicle manufacturer's service manual. These instructions may include connecting a 12-V power source to the cigarette lighter socket to maintain power to computer memories, radio-stereo, and other electronic equipment.

   List the vehicle manufacturer's instructions for disconnecting the negative battery cable.

   ____

   ____

   Have these instructions been completed on the vehicle being serviced? ☐ Yes ☐ No

   Instructor check ____
3. If the vehicle is air-bag-equipped, determine the specified waiting period after the negative battery cable is disconnected before performing service work.
   Waiting period __________
4. Disconnect the negative battery cable.

   Is the negative battery cable disconnected? ☐ Yes ☐ No

   Has the specified waiting period been completed before servicing the vehicle?
   ☐ Yes ☐ No

   Instructor check ____
5. Use a hand pump to pump all the fuel from the fuel tank. Place the fuel in the proper fuel safety containers and store this fuel away from the work area and other ignition sources.

   Has all the fuel been pumped from the tank? ☐ Yes ☐ No

   Is this fuel placed in proper fuel safety containers and stored away from the work area? ☐ Yes ☐ No

   Instructor check ____

6. Remove the fuel tank from the vehicle and store the fuel tank away from the work area and other ignition sources.

   Is the fuel tank removed? ☐ Yes ☐ No

   Fuel tank stored away from the work area? ☐ Yes ☐ No

   Instructor check ______________________________

7. Protect the interior and exterior of the vehicle from heat or sparks generated by the welding process.

   Are the vehicle's interior and exterior protected? ☐ Yes ☐ No

   Instructor check ______________________________

8. Inspect the entire frame for cracks, bends, severe corrosion, and wrinkles in the flanges.

   Defective frame conditions:

   ____

   ____

   ____

9. Remove any components that would interfere with the weld or be damaged by heat.

   Have all components been removed that would interfere with the weld or be damaged by the heat? ☐ Yes ☐ No

   Instructor check ______________________________

10. Find the extreme end of the crack and drill a 0.25 in. (6-mm) hole at this point.

    Is a 0.25 in. hole drilled at the end of the crack? ☐ Yes ☐ No

    Instructor check ______________________________

11. V-grind the entire length of the crack from the starting point to the drilled hole.

    Is the entire length of the crack V-ground? ☐ Yes ☐ No

    Instructor check ______________________________

12. The bottom of the crack should be opened 0.062 in. (2 mm) to allow proper weld penetration. A hacksaw blade may be used to open the crack.

    Is the bottom of the crack open 0.062 in. (2 mm)? ☐ Yes ☐ No

    Instructor check ______________________________

13. Arc weld the crack with the electrodes specified by the frame and/or vehicle manufacturer. Complete several passes with the arc weld to fill the crack.

    Is the crack filled with arc weld material? ☐ Yes ☐ No

    Instructor check ______________________________

14. Use a pointed welding hammer to remove slag from the exterior of the weld.

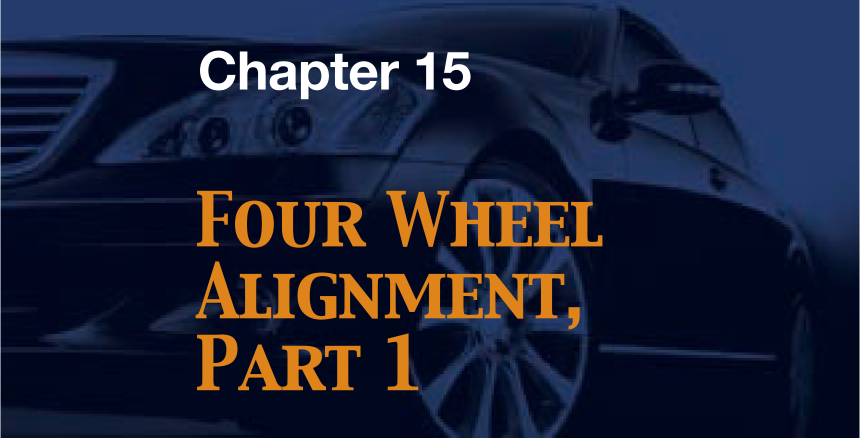
    Is the slag removed from the weld? ☐ Yes ☐ No

    Instructor check ______________________________

Instructor's Response ______________________________

____

____



Chapter 15

Four Wheel Alignment, Part 1

Upon completion and review of this chapter, you should be able to understand and describe:

- The variables that affect wheel alignment.
- Wheel alignment, and explain five reasons for performing a wheel alignment.
- Why four wheel alignment is essential on front-wheel-drive unitized body cars.
- Thrust line and geometric centerline and describe the effect of an improper thrust line on vehicle steering.
- The result of improper rear wheel toe and its effect on the thrust line.
- The causes of improper rear wheel toe.
- The causes of rear axle offset.
- Rear axle sideset, setback, and dogtracking.
- Front and rear tire tread wear caused by inaccurate rear wheel toe and thrust line settings.
- Geometric centerline alignment and explain the problem with this type of alignment.
- Thrust line alignment and describe the shortcoming of this type of alignment.
- Total four wheel alignment and explain the advantage of this type of alignment.
- The safety hazards created by incorrect wheel alignment or worn suspension and steering components.
- The effect of excessive positive camber on front suspension systems.
- Camber changes during front wheel jounce and rebound travel.
- The relationship between camber and vehicle directional stability.
- How front suspension camber and caster may be adjusted to compensate for road crown.
- The effects of positive and negative caster on directional control and steering effort.
- Positive and negative caster as they relate to ride quality.
- How higher or lower than specified front or rear suspension height affects front suspension caster.

Introduction

Automotive engineers design suspension and steering systems that provide satisfactory vehicle control with acceptable driver effort and road feel. The vehicle should have a tendency to go straight ahead without being steered. This tendency is called **directional stability**. A vehicle must have predictable directional control, which means the steering must provide a feeling that the vehicle will turn in the direction steered. The wheels must be reasonably easy to turn and tire wear should be minimized. These steering qualities and tire conditions are achieved when front and rear **wheel alignment** angles are within the vehicle manufacturer's specifications.

Wheel alignment may be defined as an adjustment and refitting of suspension parts to original specifications that ensure design performance.

The condition of suspension system components and wheel alignment are extremely important to maintaining driving safety and normal tire wear. Worn suspension components such as tie-rod ends, ball joints, and control arms can suddenly fall apart and cause complete loss of steering. This disastrous event may result in not only some very expensive property damage but also the loss of human life. When alignment angles are incorrect, an uncontrolled vehicle swerve or skid may occur during hard braking, resulting in a serious accident. Severe misalignment may reduce tire life to one-third of the normal expected tire life with correct alignment. After suspension components such as ball joints or control arms are replaced, wheel alignment is essential.

Wheel Alignment Theory

Road Variables

Road variables are differences in road surface conditions, vehicle loads, and weather conditions.

Vehicles are subjected to many **road variables** that affect wheel alignment. These variables must be counteracted by the suspension design and alignment, or steering would be very difficult. Some of the variables that affect wheel alignment and suspension design follow:

Road crown refers to the high portion in the center of the road with a gradual slope to each side.

1. **Road crown** (the curvature of the road surface)
2. Bumps and holes
3. Natural crosswinds or crosswinds created by other vehicles
4. Heavy loads or unequal weight distribution
5. Road surface friction and conditions such as ice, snow, and water
6. Tire traction and pressure
7. Side forces while cornering
8. Drive axle forces in front-wheel-drive vehicles
9. Relationship between suspension parts as the front wheels turn and move vertically when road bumps and holes are encountered

A desirable plan to reduce tire wear would be to place the front wheels and tires so they are perfectly vertical. The tires would then be flat on the road. However, if the wheels and tires are perfectly vertical, such variables as the driver entering the car, turning a corner, or adding weight to the luggage compartment would move the tire from its true vertical position. Therefore, tire wear and steering operation would be adversely affected.

Vehicle **tracking** is the straightness of the rear wheels in relation to the front wheels.

Rather than allowing the variables to adversely affect tire wear and steering operation, the suspension and steering are designed with characteristics to provide directional stability, predictable directional control, and minimum tire wear. Wheel alignment angles are designed to provide these desired requirements despite road variables. Wheel alignment angles also control the **tracking** of the rear wheels in relation to the front wheels.

Importance of Four Wheel Alignment

Shop Manual
Chapter 15, page 493

A unitized body may be called a unibody.

Until the late 1970s, most vehicles in the United States were rear-wheel drive. The majority of these vehicles had one-piece rear axle housings and frames. This type of vehicle design did not experience many rear wheel alignment problems and rear wheel alignment was usually not a concern in these years.

Beginning in the late 1970s, many domestic car makers began manufacturing front-wheel-drive cars with unitized bodies. The gasoline shortages in the 1970s and the introduction of federal corporate average fuel economy (CAFE) laws brought about a massive change to lighter weight, more fuel efficient front-wheel-drive cars. A significant number of these cars had four-wheel independent suspension systems.

Cars with unitized bodies and independent or semi-independent rear suspension systems are more likely to experience rear wheel alignment problems compared with rear-wheel-drive vehicles with frames and one-piece rear axle housings. This is especially true after collision damage. Therefore, with the introduction of unitized bodies in massive numbers, four wheel alignment became a necessity.

Rear Wheel Alignment and Vehicle Tracking Problems

Result of Proper Rear Wheel Alignment

The driver uses the steering wheel to turn the front wheels and steer the vehicle in the desired direction. However, the rear wheels determine the direction of the vehicle to a large extent. When the **thrust line** is positioned at the **geometric centerline** and the front and rear wheels are parallel to the vehicle geometric centerline, the vehicle moves straight ahead with minimum guidance from the steering wheel (Figure 15-1).

The **thrust line** is an imaginary line at a 90° angle to the centerline of the rear wheels and projected forward.

The vehicle **geometric centerline** is an imaginary line through the exact center of the front and rear wheels.

Result of Improper Rear Wheel Alignment

Rear Axle Offset. A **rear axle offset** may occur on a rear-wheel-drive vehicle with a one-piece rear axle housing or on a front-wheel-drive car with a trailing arm rear suspension. If the rear axle is offset, the thrust line is no longer at the vehicle centerline (Figure 15-2). The **thrust angle** is the angle between the geometric centerline and the thrust line.

A **rear axle offset** refers to a condition where the complete rear axle housing has rotated slightly, moving one rear wheel forward and the opposite rear wheel backward. Under this condition, the rear wheels are no longer parallel to the geometric centerline of the vehicle.

With the rear axle offset problem shown in Figure 15-2, the thrust line is positioned to the left of the geometric centerline. Under this condition, the rear wheels steer the vehicle in a large clockwise circle. If the driver's hands are removed from the steering wheel, the steering pulls to the right. This steering action is similar to the rear wheels on a forklift. The rear wheels are used to steer the forklift because of the heavy load on the front wheels. If the rear wheels are pointed toward the left, the forklift turns to the right.

On a vehicle with this problem, the left front wheel toes out and the right front wheel toes in when the vehicle is driven straight ahead. This front wheel situation occurs because the front wheels try to compensate for the rear suspension defect. The front wheels are turned slightly to the left to compensate for the drift to the right caused by the rear suspension problem. Under this condition, both the front and rear tires may have feathered tire wear.

The ideal correction for this rear suspension problem is to reposition the rear suspension so the thrust line is at the vehicle centerline, then set the front wheel toe-in to the thrust line. The rear suspension problem that we have described also causes the steering wheel to be off-center when the vehicle is driven straight ahead.

Some of the causes of rear axle offset are:

1. A broken center bolt in rear leaf spring.
2. Worn shackles in rear leaf springs.
3. A bent frame.
4. A bent subframe or floor section, unitized body.
5. Worn trailing arm bushings.
6. Bent trailing arms.

Improper Rear Wheel Toe. If the left rear wheel has excessive toe-out, the thrust line is moved to the left of the geometric center line (Figure 15-3). This defect has basically

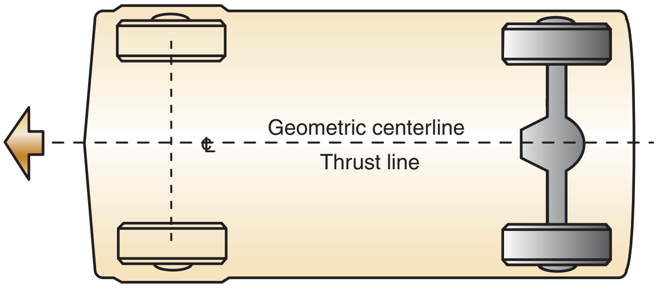


FIGURE 15-1 **Front and rear wheels parallel to the vehicle centerline.**

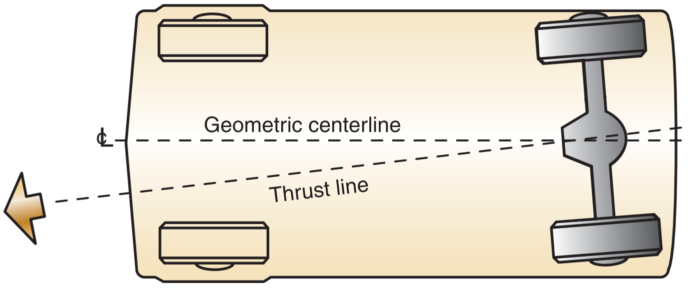


FIGURE 15-2 **Rear axle offset and improperly positioned thrust line.**

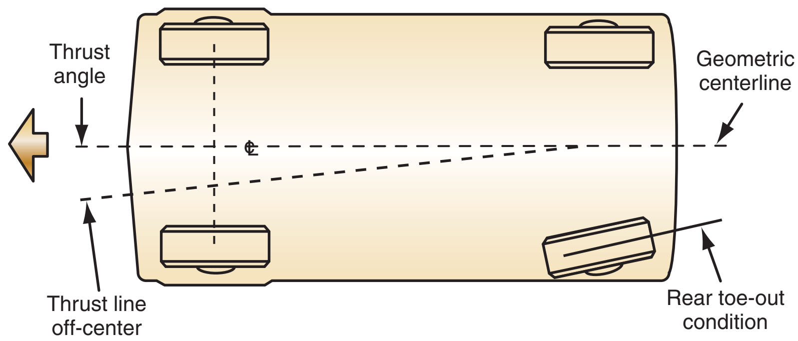


FIGURE 15-3 **Excessive toe-out on the left rear wheel moves the thrust line to the left of the geometric centerline.**

the same effect on steering as rear axle offset. Improper toe on one rear wheel is most often encountered on vehicles with independent rear suspension.

Some of the causes of improper toe on one rear wheel are:

1. A bent one-piece rear axle.
2. A bent U section in trailing arm suspension.
3. A bent rear lower control arm.
4. A worn rear lower control arm bushing.
5. A bent rear spindle.
6. An improper rear toe adjustment.

The necessary correction for this defect is to adjust the left rear wheel toe to the manufacturer's specifications. This adjustment moves the thrust line to the geometric centerline of the vehicle (Figure 15-4).

AUTHOR'S NOTE: It has been my experience that the effect of rear wheel alignment on steering pull is sometimes ignored when diagnosing a customer complaint of steering pull. If the rear axle is offset or the rear wheel toe is incorrect, the rear wheel position actually pushes the front wheels away from the straight-ahead position and causes the steering to pull to one side. This problem is more likely to occur on front-wheel-drive cars, especially those with independent rear suspension and a unitized body design. Therefore, it is very important that you perform a four wheel alignment and be sure the thrust angle is within specifications before aligning the front suspension.

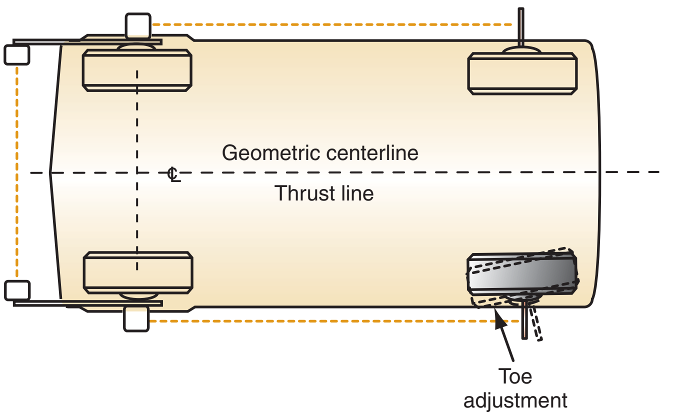


FIGURE 15-4 **Adjusting toe to specifications on the left rear wheel moves the thrust line to the geometric centerline.**

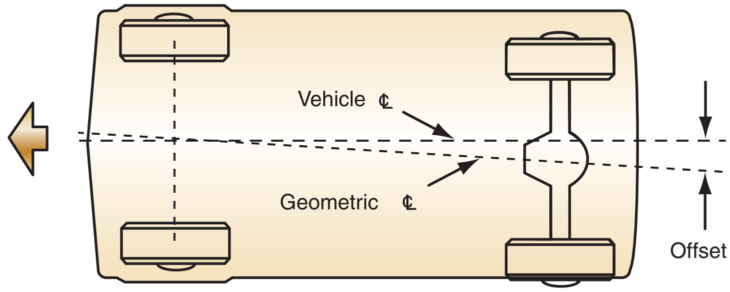


FIGURE 15-5 **Rear axle offset occurs when the rear axle assembly has moved straight sideways and the geometric centerline is shifted away from the proper vehicle centerline position.**

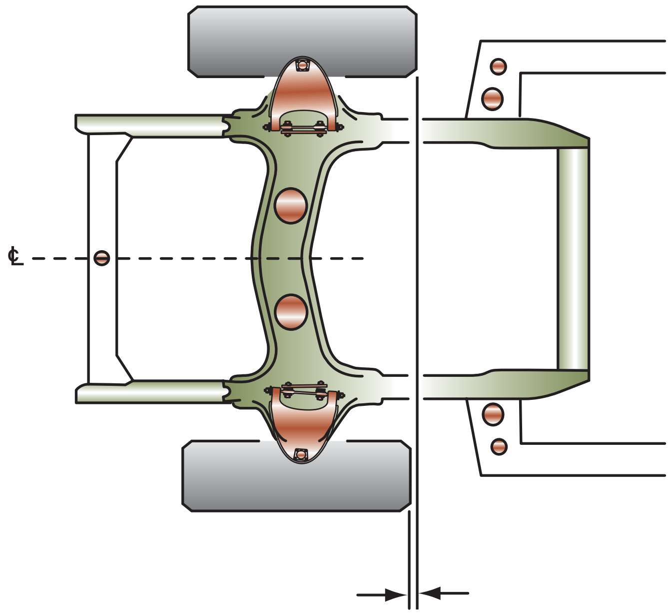


FIGURE 15-6 **Front wheel setback occurs when one front wheel is moved rearward in relation to the opposite front wheel.**

Rear Axle Sideset. When **rear axle sideset** occurs, the rear wheels are parallel to each other but the rear axle assembly has moved straight sideways so the geometric centerline is no longer at the proper vehicle centerline position (Figure 15-5). Since the rear wheels do not follow directly behind the front wheels when the vehicle is driven straight ahead, the vehicle dogtracks. Rear axle sideset does not affect steering pull as much as rear axle offset, but sideset will cause steering pull if it is severe.

In a **geometric centerline alignment**, the front wheel toe is adjusted using the geometric centerline as a reference.

Wheel Setback. Wheel setback is a condition where one front or rear wheel is moved rearward in relation to the opposite wheel (Figure 15-6). This condition is usually caused by front-end collision damage, and thus it is most likely to be a front suspension problem. However, setback may occur on independent rear suspension systems. A severe setback condition causes steering pull.

Types of Wheel Alignment

Geometric Centerline Alignment

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Toe refers to the angle between the plane of a front or rear wheel and a reference line. Either the geometric centerline or the thrust line may be used as a toe reference line. When **geometric centerline alignment** is used as a reference for front wheel toe, the toe on each front wheel

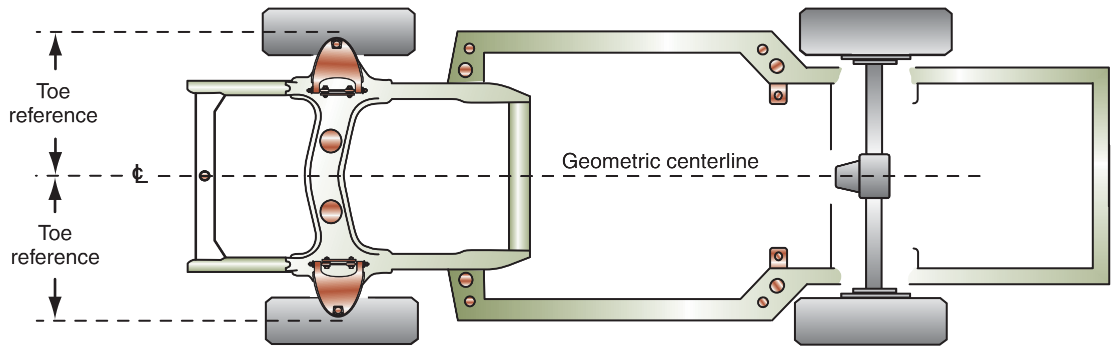

FIGURE 15-7 **Front wheel alignment with the front wheel toe referenced to the geometric centerline.**

is adjusted to specifications using the geometric centerline as a reference (Figure 15-7). This type of wheel alignment has been used for many years. It may provide a satisfactory wheel alignment if the rear wheels are properly positioned and the thrust line is at the vehicle centerline. However, if the rear wheels are not positioned properly, the thrust line is not at the geometric centerline and steering problems will occur. Therefore, geometric centerline front wheel reference ignores rear wheel misalignment.

Thrust Line Alignment

If **thrust line alignment** is used, the thrust line created by the rear wheels is used as a reference for front wheel toe adjustment (Figure 15-8). When the front wheel toe is adjusted with a thrust line reference, and this line is not at the geometric centerline, neither the front nor rear wheels are parallel to the geometric centerline. Under this condition, none of the four wheels is facing straight ahead when the vehicle is driven straight ahead. This action results in excessive wear on all four tire treads. This type of alignment ensures a centered steering wheel when the vehicle is driven straight ahead.

Four Wheel Alignment

When a **four wheel alignment** is completed, the thrust line position is measured in relation to the geometric centerline. Individual rear wheel toe-in is measured and adjusted to manufacturer's specifications. This adjustment moves the thrust line to the geometric centerline. Thrust angle is measured to be sure the thrust line is positioned at the geometric centerline. Front wheel toe is measured using the common geometric centerline and thrust line as a reference (Figure 15-9). When a four wheel alignment is completed, all four wheels are parallel to the geometric centerline and the steering wheel is centered as the vehicle is driven straight ahead. Wheel aligners have different alignment capabilities. Modern computer wheel alignment systems have four-wheel alignment capabilities, and this type of wheel alignment must be performed on today's vehicles to ensure proper steering control and vehicle safety.

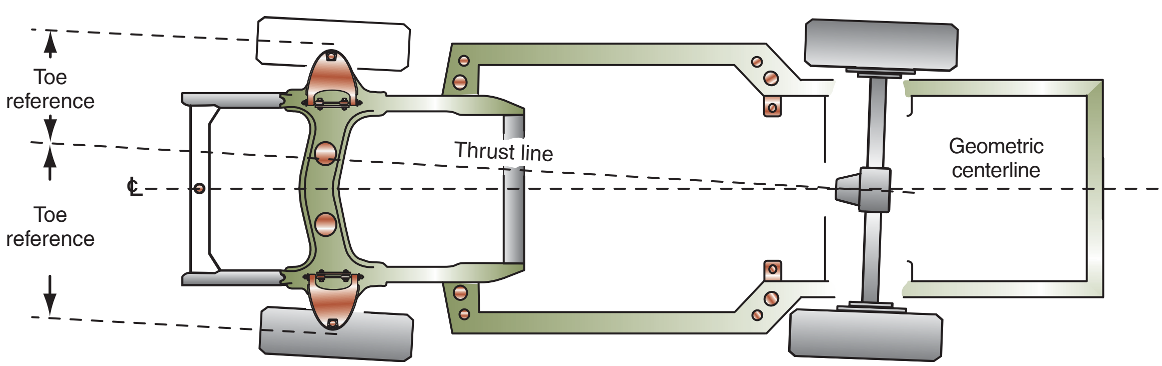

FIGURE 15-8 **Thrust line alignment with the front wheel toe referenced to the thrust line.**

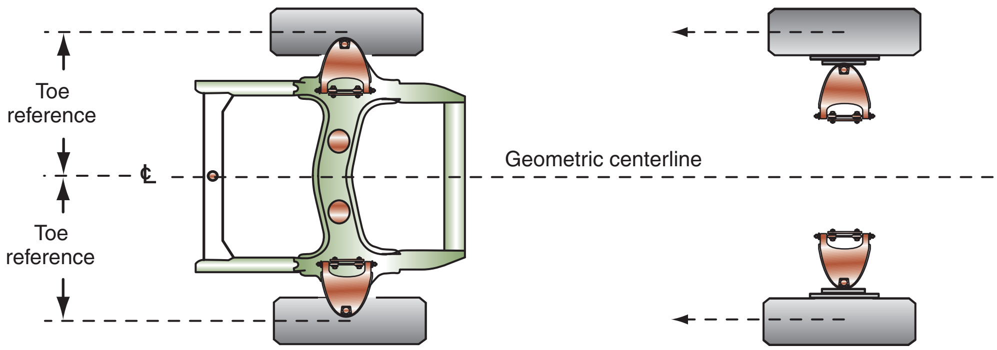

FIGURE 15-9 **Four wheel alignment with the thrust line adjusted so it is at the geometric centerline and the front wheel toe is referenced to the geometric centerline.**

The advantages of four-wheel alignment are the following:

1. *Improved fuel mileage*. After a four-wheel alignment, all four wheels are parallel, and this condition combined with proper tire inflation decreases rolling resistance, which improves fuel mileage.
2. *Longer tire life*. When all four wheels are aligned properly, tire tread wear is minimized.
3. *Improved vehicle handling*. When all four wheels are properly aligned and all steering and suspension components are in satisfactory condition, steering pulls, vibrations, and abnormal steering conditions are eliminated to ensure improved vehicle handling.
4. *Safer driving*. Proper alignment of all four wheels plus inspection and replacement of all worn or defective steering and suspension components improves vehicle handling, and this reduces the possibility of a collision and provides safer driving.

Computer Alignment Systems

Computer Wheel Aligner Features

Some computer wheel aligners have four high-resolution digital cameras that measure wheel target position and orientation. The front and rear wheel alignment angles are sensed by the digital cameras and wheel targets and then displayed on the wheel alignment monitor. The vehicle is raised to a comfortable working height on the aligner lift, and two digital cameras are mounted in each end of a crossbar on a post in front of the vehicle (Figure 15-10). The post and crossbar height may be adjusted to match the vehicle height.

FIGURE 15-10 **Computer wheel aligner with digital cameras and wheel targets.**

A Bit of History

Early attempts at rear wheel alignment were slow and lacked precision. These attempts at rear wheel alignment included the use of a track bar and even backing the rear wheels of a car onto a front wheel aligner to align the rear wheels. To meet the need for fast, accurate front and rear wheel alignment, wheel alignment manufacturers designed computer wheel aligners. The technology in this equipment has greatly improved since the first models were introduced.

FIGURE 15-11 **One digital camera is aimed at each wheel target.**

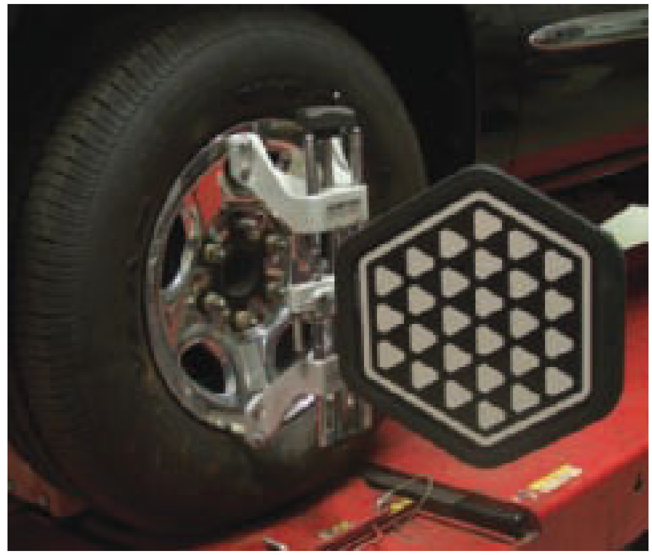

FIGURE 15-12 **Each target contains a polished aluminum face plate with no electronics, glass, or cables.**

One digital camera is aimed at each wheel target (Figure 15-11). A target is mounted on each wheel with a self-centering adapter. The adapters are adjustable to fit rims up to 24 in. (60 cm) in diameter. The targets contain a polished aluminum faceplate that acts as a mirror (Figure 15-12). The targets do not contain any electronics, glass, or cables, and they do not require calibration. The targets are also lightweight and do not require any maintenance.

This type of computer aligner is very simple to use. After the pre-alignment procedures and checks have been performed on the vehicle, and the vehicle is positioned at the desired height and position on the lift and turntables, the first step is to mount the wheel targets on the wheels. The second step is to roll the vehicle back a short distance until the on-screen indicators on the monitor turn green. The third step is to roll the vehicle forward and stop the vehicle so the front wheels are centered on the turntables. The fourth step is to observe all the front and rear camber and toe angles displayed on the monitor.

A remote control is wired into the monitor so the technician can perform the same functions when the monitor is not in the technician's view. A handheld remote control is used to measure the vehicle ride height (Figure 15-13). This remote is held against the lower edge of the fender well to measure the ride height, and the remote transmits the ride height measurement electronically to the console and monitor.

FIGURE 15-13 **A handheld remote control transmits ride height measurements electronically to the console and monitor.**

FIGURE 15-14 **Cordless wheel sensor containing a high-frequency transmitter.**

FIGURE 15-15 **Computer wheel aligner with data receiver on top of the monitor.**

On some computer wheel aligners the **wheel sensors** contain a microprocessor and a **high-frequency transmitter** that acquire measurements and process data and then send these data to a **receiver** mounted on top of the wheel alignment monitor (Figures 15-14 and 15-15). This type of wheel sensor does not require any cables connected between the sensors and the computer wheel aligner. The data from this type of wheel sensor are virtually uninterruptible, even by solid objects. When these wheel sensors are stored on the computer wheel aligner, a "docking station" feature charges the batteries in the wheel sensors. The front wheel sensors have optical arms that project ahead of the tires to provide front toe readings. Some rear wheel sensors also have optical arms that project behind the rear tires (Figure 15-16). This type of rear wheel sensor measures rear wheel setback.

Wheel sensors are mounted on each wheel, and these sensors transmit wheel alignment data to the computer wheel aligner.

A **high-frequency transmitter** is contained in many wheel sensors. This transmitter sends data to a receiver on top of the monitor.

On some computer alignment systems, the reference signals between the wheel sensors are provided by light-emitting diodes (LEDs) or electronic signals. Cables are connected from the wheel units to the computer aligner. Reference signals between the wheel units are provided by strings on some older model computer alignment systems (Figure 15-17). Most wheel sensors provide wheel runout compensation. Since the wheel unit is clamped to the rim, a bent rim will affect the alignment readings. On older computer wheel aligners, the technician had to perform a wheel runout check at each wheel. Newer wheel units use audible and visual prompts on the monitor screen to inform the technician if the wheel sensors require leveling or calibration. Wheel runout compensation may be completed by pressing a button on the wheel sensor. Wheel sensor leveling is done by adjusting the sensor level control.

FIGURE 15-16 **Front and rear wheel sensors with optical arms.**

FIGURE 15-17 **Front wheel sensor with optical arm and string connected to the rear wheel sensor.**

A **receiver** on the computer wheel aligner receives signals from the wheel sensors.

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CAUTION:
When using a computer wheel aligner, the equipment manufacturer's recommended alignment procedures must be followed to provide accurate readings and adjustments.

Computer alignment systems have the capability to measure thrust angle and setback as well as other front and rear alignment angles. A typical computer wheel aligner has the following features:

1. Color monitor and computer (Figure 15-18).
2. Computer software program stored on a hard disc drive. This program contains vehicle four-wheel alignment procedures and diagnostic drawings.
3. Compact disc (CD) or digital video disk (DVD) drive. The vehicle specifications and alignment program may be contained on CDs or DVDs, and updates are possible by replacing the CDs or DVDs (Figure 15-19). Wheel alignment specifications include domestic and imported vehicles for the current year and a minimum of 10 previous years.
4. The software in some computer wheel aligners includes a CD or DVD image database containing 2,100 digital photos of the adjustment and inspection points. In some computer aligners, a list of inspection points appears on the left of the screen. When the operator clicks on a listed inspection point, the matching photo appears, illustrating the selected inspection point (Figure 15-20). Special digital photos are available for inspection of the cradle and cradle-to-body alignment.
5. Live action inspection videos may be accessed instantly from the inspection screen. These inspection videos are part of the 142-video training library.

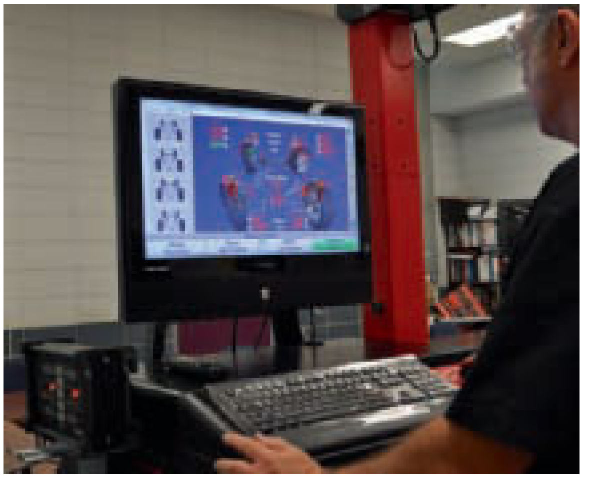

FIGURE 15-18 **Computer wheel aligner.**

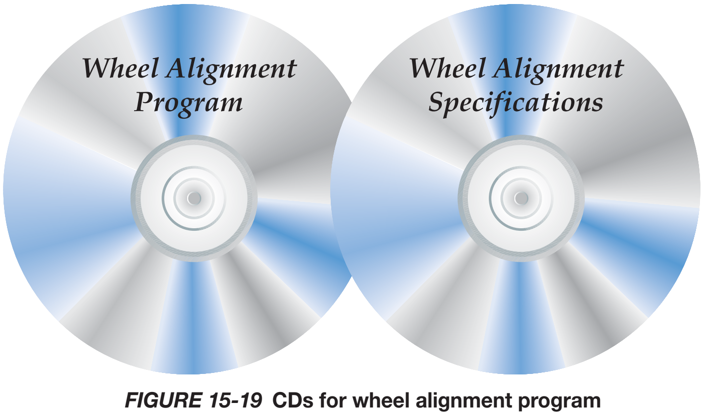

FIGURE 15-19 **CDs for wheel alignment program and specifications.**

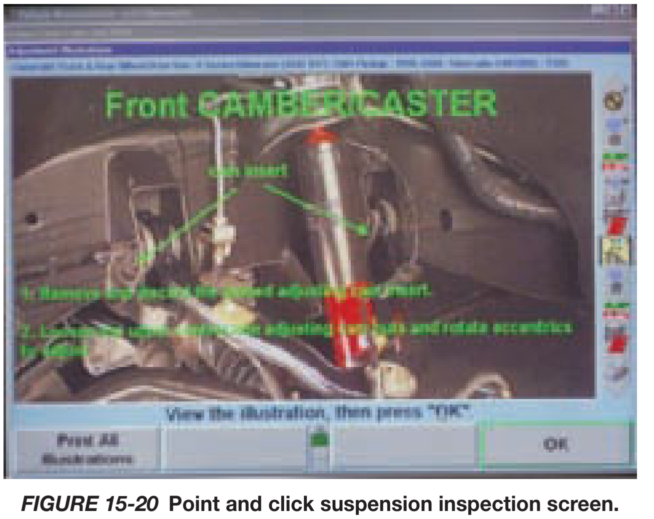

FIGURE 15-20 **Point and click suspension inspection screen.**

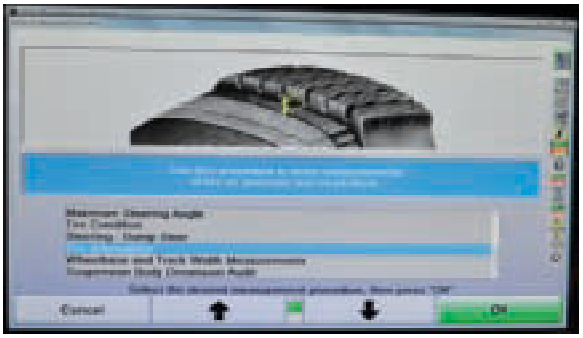

FIGURE 15-21 **Tire inspection screen.**

6. A tire inspection screen illustrates various types of tire tread wear and the related causes (Figure 15-21). This screen may be printed out and shown to the customer.
7. Measurement and adjustment screens illustrate suspension measurements. If a measurement is within specifications, the measurement is illustrated with a green bar and an arrow indicates the measurement. A red measurement bar indicates the adjustment is not within specifications (Figure 15-22). In the adjustment mode, the measurement remains on the screen, and as the necessary suspension adjustment is performed, the adjustment bar turns green when the arrow moves within specifications.
8. An alignment procedure bar is available in some computer aligners. This vertical bar contains an icon for each step in an alignment procedure (Figure 15-23). These steps are arranged in the proper sequence. A check mark appears when a step has been completed, and the technician may select and click any step to move to that adjustment.
9. Correction kit videos may be accessed to illustrate the installation of aftermarket wheel alignment correction kits. Special tools videos are available in the computer wheel aligner software. These videos indicate the special wheel alignment adjustment tools required for the vehicle being aligned. Operation videos may be accessed to show the technician how to operate the computer wheel aligner.
10. Some computer wheel aligners have multilingual capabilities. These capabilities usually include three languages; however, up to twenty languages may be available from the equipment manufacturer.
11. Full-function keyboard allows the technician to enter such information as the customer's name and address and the make and year of the vehicle.
12. Set of four self-centering adjustable rim clamps and four wheel sensors.

CAUTION:
Because wheel units contain sensitive electronic circuits, excessive shock such as dropping them on the floor can damage them.

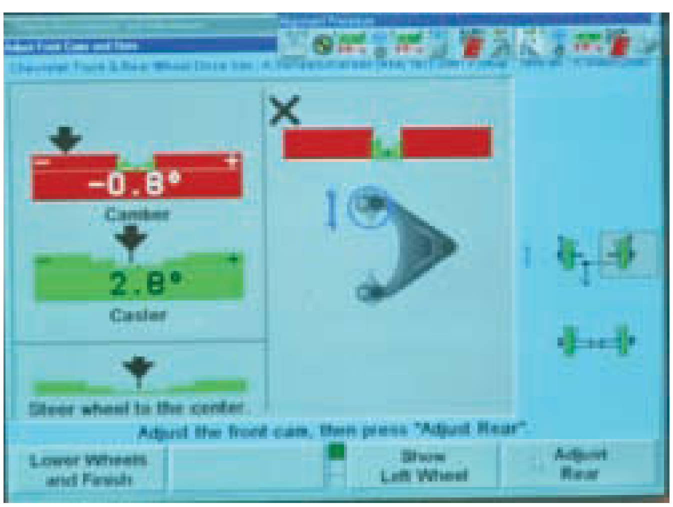

FIGURE 15-22 **Wheel alignment adjustment screen.**

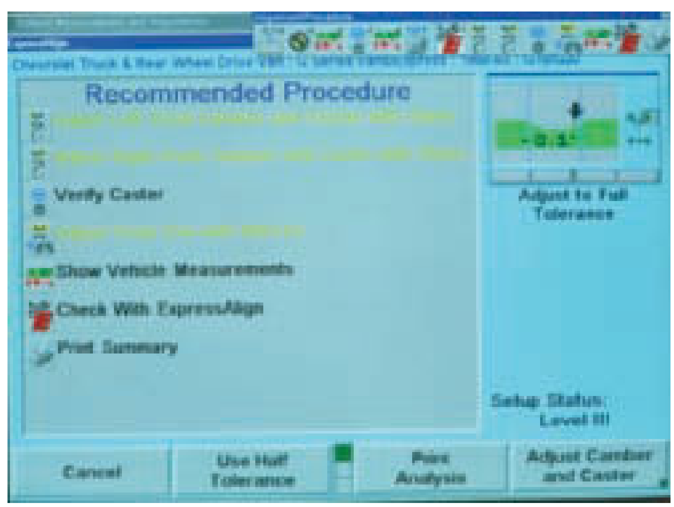

FIGURE 15-23 **Wheel alignment procedure screen.**

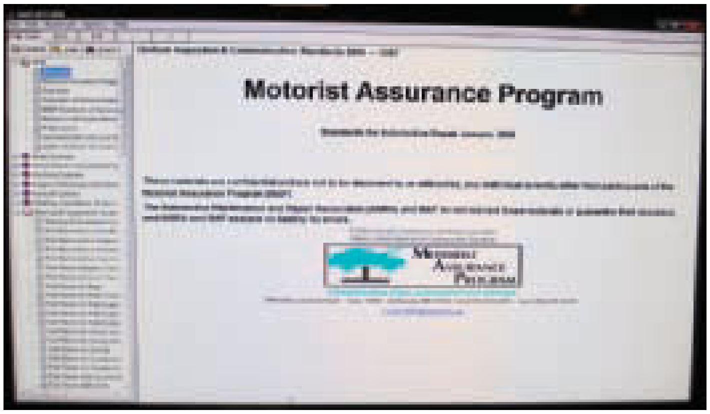

FIGURE 15-24 **The Motorist Assurance Program (MAP) parts inspection guidelines may be accessed in computer wheel aligners.**

FIGURE 15-25 **Wheel Alignment on CD or DVD for computer wheel aligners.**

The **Motorist Assurance Program (MAP)** improves automotive customer satisfaction by establishing uniform inspection guidelines.

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13. Full-function remote control that allows the technician to control the alignment program and see the results of suspension adjustments while working under the vehicle.
14. Color or laser printer provides detailed wheel alignment reports for the customer and specific alignment messages and diagrams for the technician.
15. In some computer wheel aligners, the **Motorist Assurance Program (MAP)** uniform inspection guidelines may be accessed for many steering, suspension, and brake components (Figure 15-24). The MAP program establishes uniform parts inspection guidelines to improve customer satisfaction with the automotive industry.
16. A variety of software programs are available with some computer wheel aligners. Much of the software may be extra-cost options. This software may include:
    - Wheel alignment software on CD or DVD: This software provides the technician with a very extensive vehicle information database as well as many patented adjustment and productivity features (Figure 15-25).
    - Specific computer software provides service bulletins and other information on domestic and import vehicles (Figures 15-26 and 15-27). Some computer software also provides labor estimates for automotive repairs.

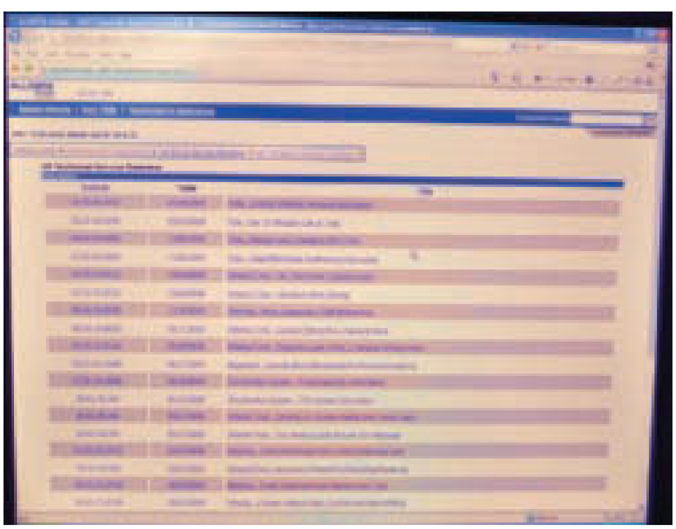

FIGURE 15-26 **Some computer software provides service bulletin information for suspension and steering problems.**

FIGURE 15-27 **Specific computer software provides diagnostic and service information in some computer wheel aligners.**

Camber Fundamentals

Camber Definition

Camber refers to the tilt of a line through the tire and wheel centerline in relation to the true vertical centerline of the tire and wheel.

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Positive camber is obtained when the top of the tire and wheel is tilted outward, away from the true vertical line of the wheel assembly. **Negative camber** occurs when the tire and wheel centerline tilts inward in relation to the wheel assembly true vertical centerline (Figure 15-28). The camber may be adjusted with the cam on the upper strut-to-steering knuckle bolt on some MacPherson strut front suspension systems. Negative and positive camber angles are the same on a short-and-long arm front suspension system as they are on a MacPherson strut suspension system (Figure 15-29).

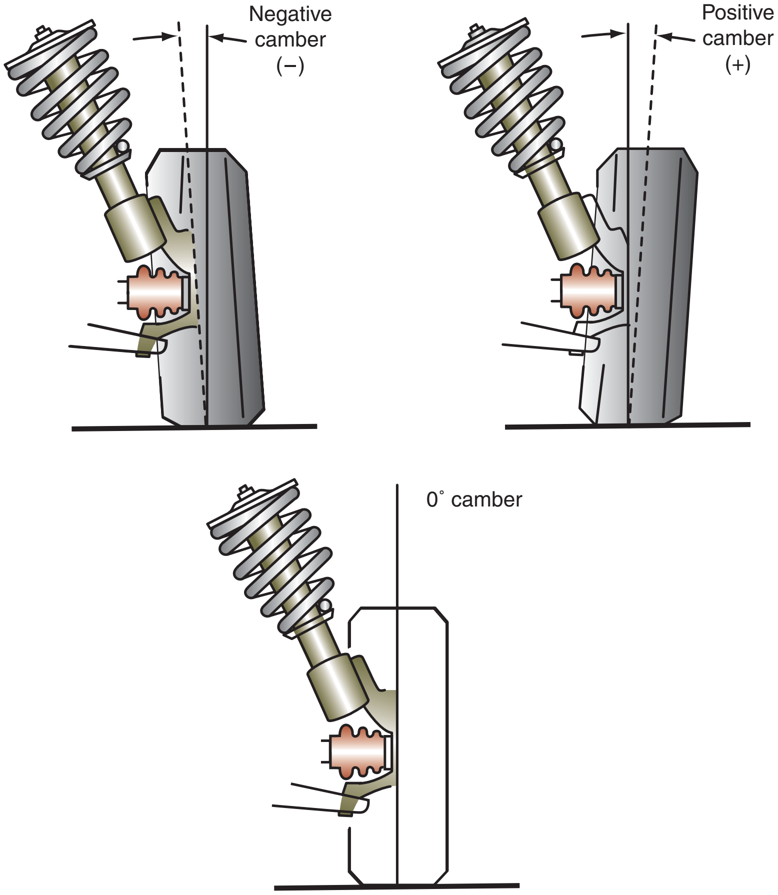

FIGURE 15-28 **Negative and Positive camber angles on a MacPherson strut front suspension system.**

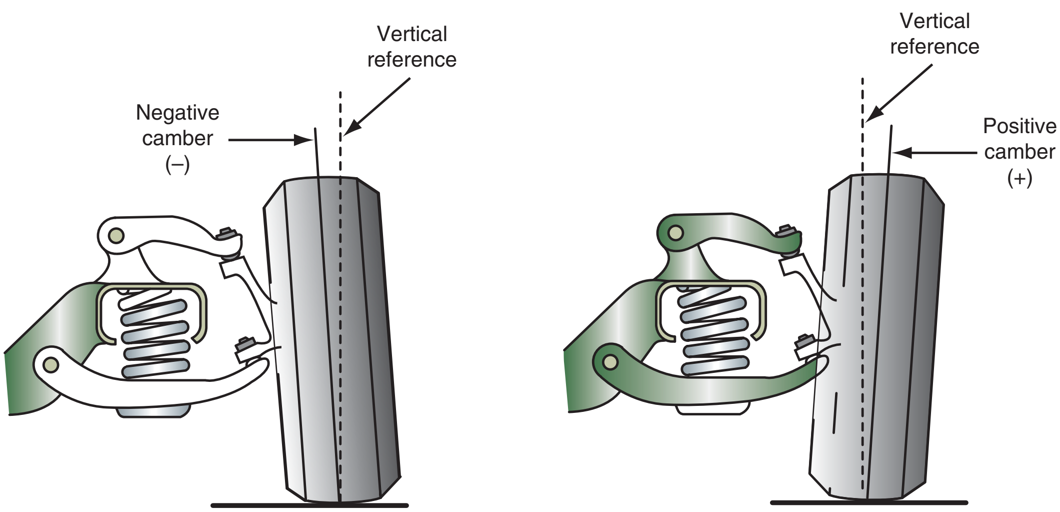

FIGURE 15-29 **Negative and positive camber angles on a short-and-long arm front suspension system.**

Front cradle position is extremely important to provide proper front wheel camber on a front-wheel-drive vehicle. For example, if the vehicle is involved in a side collision and most of the collision force is supplied to the front wheel and chassis, the cradle may be pushed sideways. On the side of the vehicle impacted during the collision, the front suspension and cradle may be pushed inward, and the other side of the cradle may be forced outward. When the front suspension and cradle are moved inward, the camber on that side of the vehicle becomes more positive. When the cradle, suspension, and bottom of the wheel on the opposite side are moved outward, the camber is moved toward a negative position.

Driving Conditions Affecting Camber

Jounce and Rebound

Upward wheel movements are referred to as **jounce**, whereas downward wheel movements are termed **rebound**. On most modern suspension systems during wheel jounce, the top of the wheel moves outward and creates a more positive camber angle (Figure 15-30). During wheel rebound, it is desirable to have very little camber change to minimize tire tread wear. A short-and-long arm front suspension system will have a slightly negative camber during wheel rebound travel (Figure 15-31).

Cornering Forces

During hard cornering at high speeds, centrifugal force attempts to move the vehicle sideways to the outside of the turn. Under this condition, more vehicle weight is transferred to the side of the vehicle on the outside of the curve. Therefore, the front suspension on the outside of the curve is forced downward, whereas the front suspension on the inside of the curve is lifted upward. When this action occurs, the camber on the inside wheel becomes less positive and the inside edge of the tire grips the road surface to help prevent sideways skidding (Figure 15-32).

Simultaneously, the camber on the outside wheel moves to a slightly more positive position. This action on the outside wheel causes the outside edge of the tire to grip the road surface, which helps prevent sideways skidding (Figure 15-33). Frequent, hard, high-speed cornering causes wear on the edges of the tire treads.

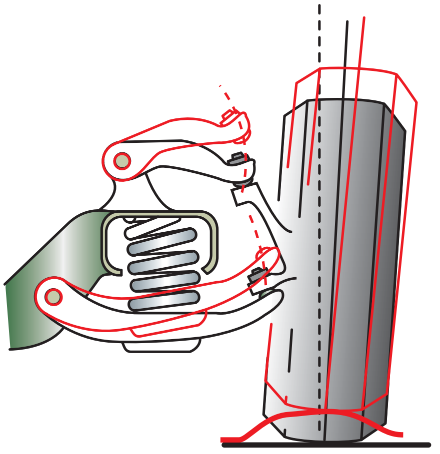

FIGURE 15-30 **Camber change during wheel jounce.**

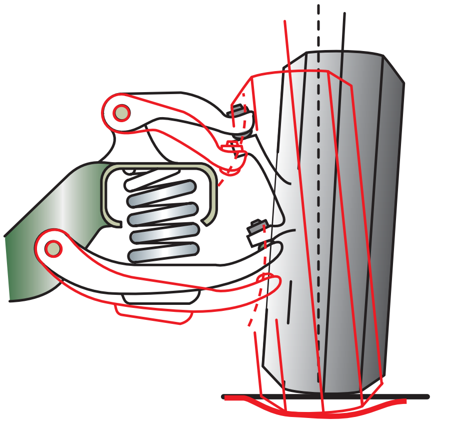

FIGURE 15-31 **Camber change during wheel rebound.**

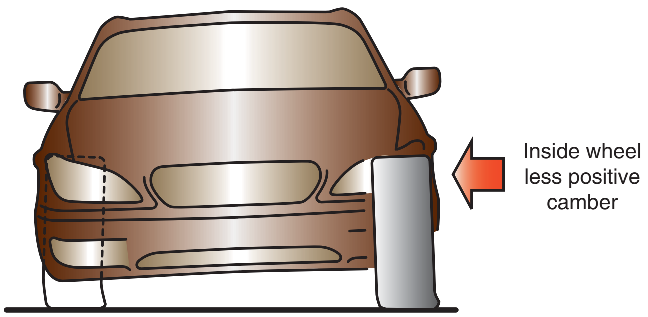

FIGURE 15-32 **While cornering at high speed, the camber on the inside front wheel becomes less positive and the inside edge of the tire grips the road surface to resist lateral skidding.**

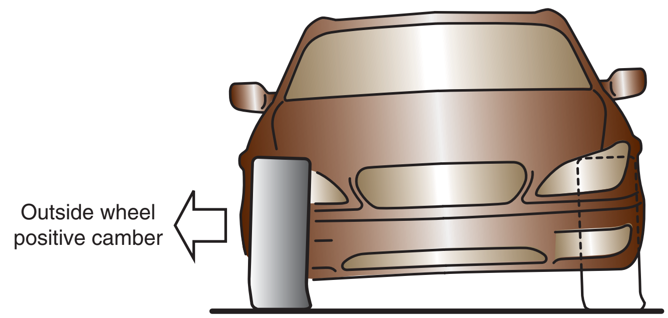

FIGURE 15-33 **While cornering at high speed, the camber on the outside front wheel moves to a slightly more positive position and the outside edge of the tire grips the road surface to resist lateral skidding.**

Tire Tread Wear

The camber angle may be referred to as one of the tire wear alignment angles. When the front wheels are adjusted to the manufacturer's specified camber setting, the front wheels will remain at, or very close to, the 0° camber position during average driving conditions. Therefore, maximum tire tread life and directional stability are maintained.

If a front wheel has excessive positive camber, the wheel is tilted outward and the vehicle weight is concentrated on the outside edge of the tire. Under this condition, the outside edge of the tire has a smaller diameter than the inside tire edge. Therefore, the outside tire edge has to complete more revolutions to travel the same distance as the inside tire edge. Since both edges are on the same tire, the outside edge must slip and scuff on the road surface as the tire and wheel revolve (Figure 15-34).

Excessive negative camber tilts the wheel inward and concentrates the vehicle weight on the inside edge of the tire. This condition causes wear and scuffing on the inside edge of the tire tread (Figure 15-35). Therefore, correct camber adjustment is extremely important to providing normal tire tread life.

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WARNING: Improper camber adjustment may result in rapid tire tread wear and steering pull, which is a vehicle safety hazard.

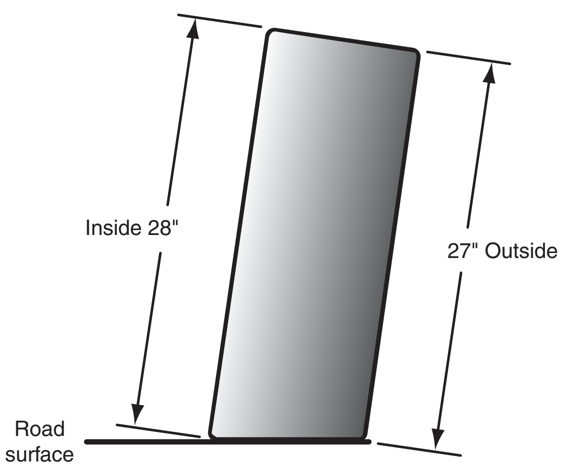

FIGURE 15-34 **Excessive positive camber causes a smaller diameter on the outside edge of the tire compared to the inside edge of the tire.**

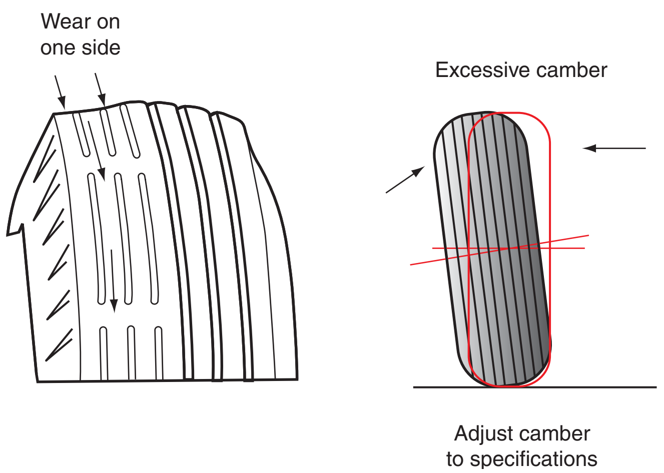

FIGURE 15-35 **Tire tread wear caused by incorrect camber adjustment.**

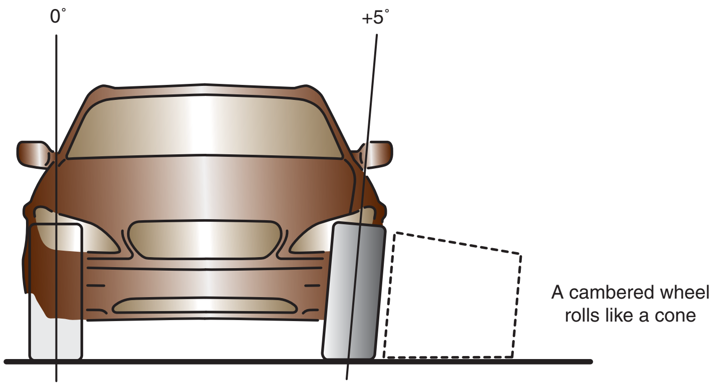

FIGURE 15-36 **A wheel turns in the direction of the tilt.**

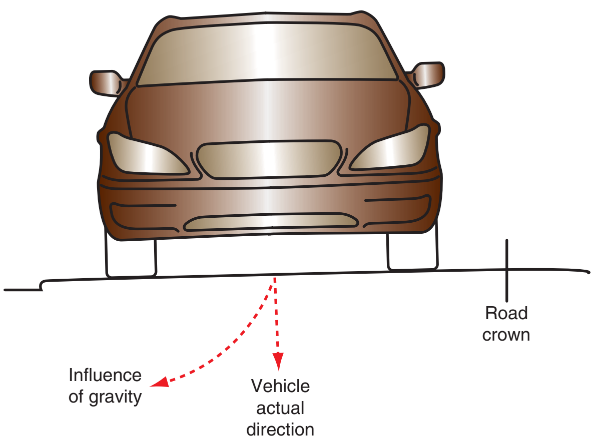

FIGURE 15-37 **A crowned road surface causes the vehicle steering to pull to the right.**

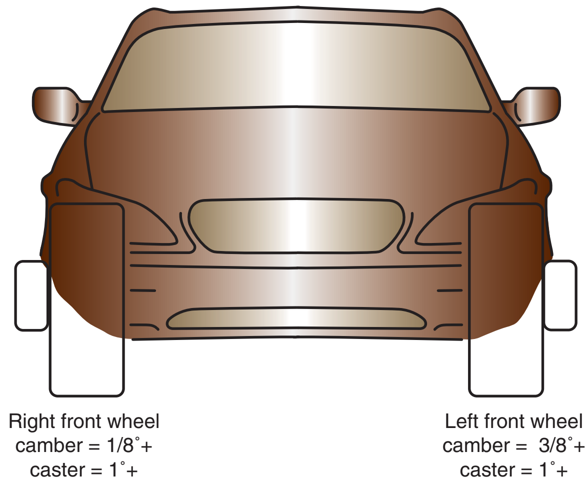

FIGURE 15-38 **Camber setting to offset road crown.**

Road Crown

A wheel that is tilted tends to steer in the direction it is tilted (Figure 15-36). For example, a bicycle rider tilts the bicycle in the direction he or she wishes to turn, making the turning process easier.

When camber angles are equal on both front wheels, the camber steering forces are equal, and the vehicle tends to maintain a straight-line position. If the camber on the front wheels is significantly unequal, the vehicle will drift to the side with the greatest degree of positive camber.

Crowned highway design prevents water buildup on the driving surface. When a vehicle is driven on a crowned road, it is actually driven on a slight slope, which causes the vehicle steering to pull toward the right (Figure 15-37). Some car manufacturers use the pulling effect of camber to offset this pull to the right caused by road crown. In these vehicles, the left front wheel may have 1/4° to 1/2° more positive camber than the right front wheel.

When the camber on the front wheels is adjusted to the manufacturer's specifications, vehicle directional stability is maintained. If the camber adjustment on the left front wheel is used to offset road crown, the caster on both front wheels must be the same (Figure 15-38).

Caster Fundamentals

Caster Definition

On a short-and-long arm suspension system, the caster line intersects the center of the upper and lower ball joints. **Positive caster** occurs when the caster line is tilted backward toward the rear of the vehicle in relation to the vertical centerline of the spindle and wheel viewed from the side (Figure 15-39).

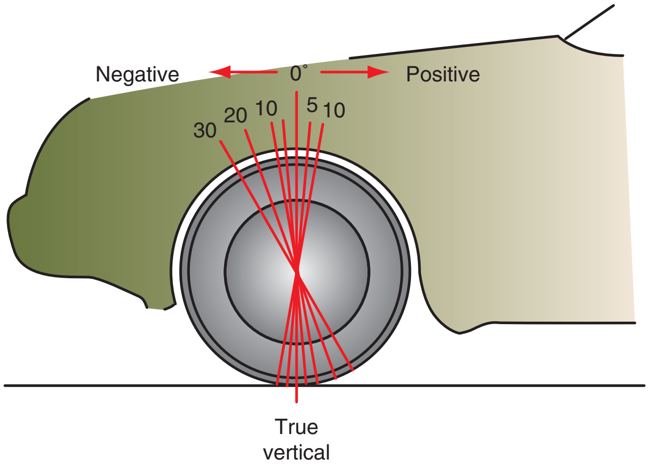

FIGURE 15-39 **Positive and negative caster.**

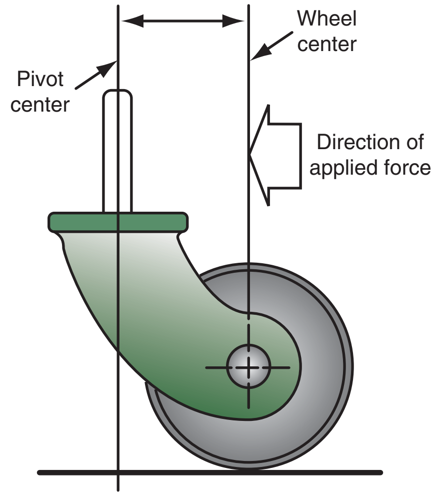

FIGURE 15-40 **Caster action on furniture.**

Negative caster occurs when the centerline of the upper strut mount and ball joint is tilted toward the front of the vehicle in relation to the spindle and wheel vertical centerline.

Effects of Positive Caster

If a piece of furniture mounted on casters is pushed, the casters turn on their pivots to bring the wheels into line with the pushing force applied to the furniture. Therefore, the furniture moves easily in a straight line (Figure 15-40).

Any force exerted on the pivot causes the wheel to turn until it is lined up with the force on the pivot, because the weight on the wheel results in resistance to wheel movement (Figure 15-41).

Most bicycles are designed with positive caster. The weight of the bicycle and rider is projected through the bicycle front forks to the road surface. The tire pivots on the vertical centerline of the spindle and wheel when the handle bars and front wheel are turned. Notice that the caster line through the center of the front forks is tilted rearward in relation to the vertical centerline of the spindle and wheel as viewed from the side (Figure 15-42).

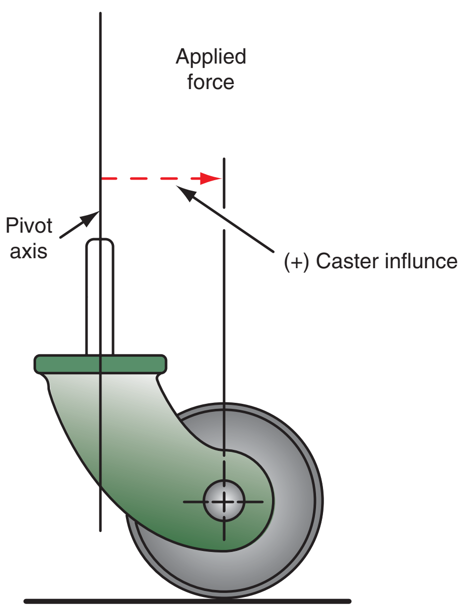

FIGURE 15-41 **Furniture caster wheel aligned with the force on the pivot.**

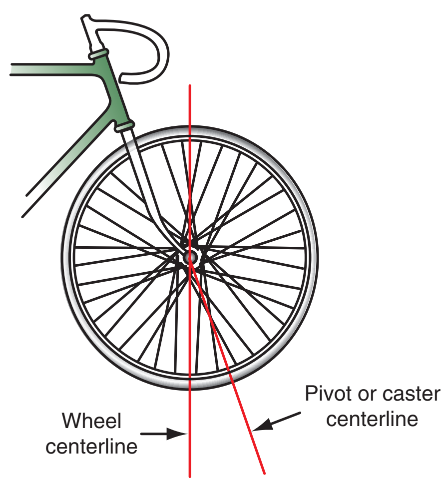

FIGURE 15-42 **Caster line on a bicycle.**

Since the pivot point is behind the caster line where the bicycle weight is projected against the road surface, the front wheel tends to return to the straight-ahead position after a turn. The wheel also tends to remain in the straight-ahead position as the bicycle is driven. Therefore, the caster angle on a bicycle front wheel provides the same action as the caster angle on a piece of furniture.

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Positive caster projects the vehicle weight ahead of the wheel centerline, whereas negative caster projects the vehicle weight behind the wheel centerline. Since positive caster causes a larger tire contact area behind the caster pivot point, this large contact area tends to follow the pivot point. This action tends to return the wheels to a straight-ahead position after a turn. It also helps maintain the straight-ahead position. Positive caster increases steering effort because the tendency of the tires to remain in the straight-ahead position must be overcome during a turn. The returning force to the straight-ahead position is proportional to the amount of positive caster. Positive caster helps maintain vehicle directional stability.

Excessive positive caster is undesirable because it increases steering effort and creates a very rapid steering wheel return. If the caster angle were 0°, the front spindles would rotate horizontally in relation to the road surface. However, a positive caster angle causes the left front spindle to tilt toward the road surface during a left turn (Figure 15-43).

This downward spindle movement tends to drive the tire into the road surface. Since this action cannot take place, the left side of the suspension and chassis is lifted. When the driver begins to return the wheel to the centered position, gravity forces the vehicle weight to its lowest position, which helps return the steering wheel to the straight-ahead position. Excessive positive caster increases the left front spindle downward tilt during a left turn, which increases the suspension and chassis lift. Therefore, excessive positive caster increases steering effort. The same action occurs at the right front spindle, but this spindle tilts downward during a right turn.

Harsh riding may be caused by excessive positive caster because the caster line is actually aimed at some road irregularities (Figure 15-44). Excessive positive caster may cause the front wheels to shimmy from side to side at low speeds.

When the caster line is aimed directly at the road irregularity, road shock is transmitted through the ball joint and upper strut mount to the suspension and chassis. A small degree of positive caster or a negative caster setting allows the front wheel to roll into a road depression without the caster line being aimed at the hole in the road. Therefore, this type of caster line improves ride quality.

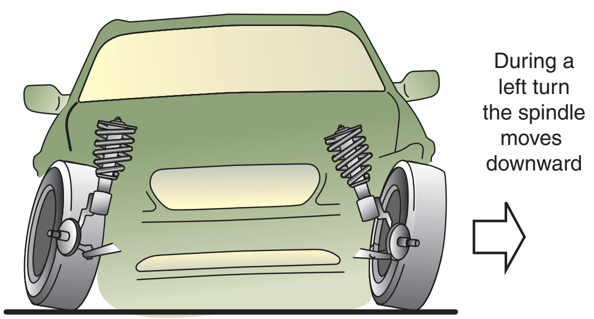


FIGURE 15-43 **Left front spindle movement during a left turn.**

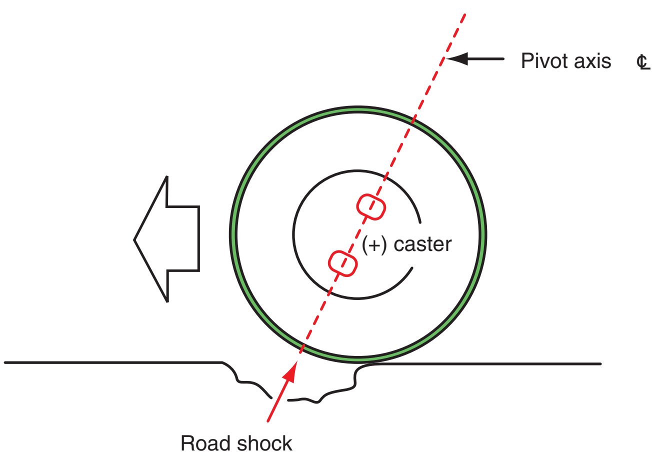


FIGURE 15-44 **Harsh riding quality caused by excessive positive caster.**

Positive caster is used on most front-wheel-drive vehicles. If one front wheel has more positive caster than the other front wheel, the steering pulls toward the side with the least amount of positive caster.

Improper front wheel caster may be caused by an improperly positioned front cradle on a front-wheel-drive car. For example, if one or both sides of the cradle are driven rearward in a front-end collision, the front wheel caster is moved from a positive position toward a negative position. This condition may cause steering wander, reduced directional control, and slower steering wheel return.

Some car manufacturers recommend less positive caster on the left front wheel than on the right front wheel to offset the steering pull to the right caused by the road crown. If the caster adjustment is used to compensate for road crown, the camber on both front wheels should be the same. The most important facts about positive caster are the following:

1. Positive caster helps the front wheels return to the straight-ahead position after a turn.
2. Correct positive caster provides improved directional stability of a vehicle.
3. Excessive positive caster produces harsh riding quality.
4. Excessive positive caster promotes sideways front **wheel shimmy**.
5. The left front wheel may be adjusted with less positive caster than the right front wheel to compensate for road crown.

Rapid side-to-side wheel movement may be called **wheel shimmy**.

Effects of Negative Caster

Negative caster moves the centerline of the upper strut mount and lower ball joint behind the vertical centerline of the spindle and wheel at the road surface. If this condition is present, the friction of the tire causes the tire to pivot around the point where the centerline of the upper strut mount and ball joint meets the road surface. When this occurs, the wheel is pulled away from the straight-ahead position, which decreases directional stability.

Negative caster reduces steering effort. Since excessive positive caster increases road shock transmitted to the suspension and chassis, negative caster reduces this shock and improves ride quality. This improvement occurs because the front wheel rolls into a road depression without the caster line being aimed at the hole in the road.

Effects of Suspension Height on Caster

When the rear springs become sagged or overloaded, the caster on the front wheels becomes more positive. This action explains why front wheel shimmy may occur when a trunk is severely overloaded.

If the rear suspension height is above the vehicle manufacturer's specification, the caster on the front wheels becomes less positive. Under this condition, the front wheel caster may change from positive to negative. This explains why a vehicle may have reduced directional stability and control when the rear suspension height is raised.

On many short-and-long arm front suspension systems, the inner front end of the upper control arm is higher than the inner rear side of this arm where it is attached to the frame. This design causes the front wheel caster to become more positive if the front suspension height is lowered. When the front suspension height is above the vehicle manufacturer's specification, the front wheel caster becomes less positive.

Most front-wheel-drive cars have a MacPherson strut front suspension system with a slightly positive caster setting. Therefore, the top strut mount is tilted rearward. If the front suspension height is lowered on this type of front suspension system, the front wheel caster becomes less positive. Conversely, if the suspension height is raised,

positive caster increases. The most important facts about negative caster include the following:

1. Negative caster does not help return the front wheels to the straight-ahead position after a turn.
2. Negative caster contributes to directional instability and reduced directional control.
3. Negative caster does not contribute to front wheel shimmy.
4. Negative caster reduces road shock transmitted to the suspension and chassis.

Safety Factors and Caster

Directional Control

As explained earlier in this chapter, positive caster provides increased directional stability and control, whereas negative caster reduces directional stability. Therefore, front wheel caster must be adjusted to the manufacturer's specifications to maintain vehicle directional control and safe handling characteristics.

Suspension Height

We have already explained how incorrect front or rear suspension height results in changes in front wheel caster. Therefore, abnormal suspension heights may contribute to reduced directional control and unsafe steering characteristics.

WARNING: Improper caster adjustment may result in decreased directional stability of the vehicle and reduced driving safety.

Torque steer may be defined as the tendency of the steering to pull to one side during hard acceleration.

Bump steer is the tendency of the steering to veer suddenly in one direction when one or both of the front wheels strikes a bump.

When **memory steer** occurs, the vehicle doesn't want to steer straight ahead after a turn because the steering does not return to the straight-ahead position.

Steering Terminology

In the automotive service industry, certain terms are used for specific steering problems. Some of these problems are related to camber and caster, others are caused by various suspension or steering defects. Technicians must be familiar with both the steering terminology and the causes of the problems.

A front-wheel-drive vehicle with unequal-length drive axles produces some **torque steer** on hard acceleration. Some front-wheel-drive vehicles, especially those with higher horsepower, have equal-length front drive axles to reduce torque steer. On a front-wheel-drive vehicle, torque steer is aggravated by different tire tread designs on the front tires or uneven wear on the front tires.

Bump steer occurs if the tie-rods are not the same height, meaning one of the tie-rods is not parallel to the lower control arm. This condition may be caused by a bent or worn idler arm or pitman arm on a parallelogram steering linkage. On a rack and pinion steering system, worn steering gear mounting bushings may cause this unparallel condition between one of the tie-rods and the lower control arm.

Memory steer may be caused by a binding condition in the steering column or in the steering shaft universal joints. A binding upper strut mount may result in memory steer. Negative caster or reduced positive caster also causes memory steer.

Steering pull is the tendency of the steering to gradually pull to the right or left when the vehicle is driven straight ahead on a level road. Steering pull or drift may be caused by improper caster or camber adjustments. **Steering drift** is the tendency of the steering to slowly drift to the right or left when driving straight ahead on a level road.

When **steering wander** occurs, the vehicle tends to steer in either direction rather than straight ahead on a level road surface. Steering wander may be caused by improper caster adjustment.

Summary

- Front-wheel-drive cars with unitized bodies are more subject to rear wheel alignment problems compared with rear-wheel-drive cars with frames and one-piece rear axle housings.
- The vehicle geometric centerline is an imaginary line through the exact center of the front and rear wheels.
- The thrust line is an imaginary line at a 90° angle to the rear wheel centerline and projected forward.
- A rear axle offset occurs when the complete rear axle is rotated slightly, moving one rear wheel backward and the opposite rear wheel forward.
- Dogtracking is a term applied to a condition where the rear wheels are not directly following the front wheels.
- Rear axle offset or improper toe on one rear wheel causes steering pull to one side and tire tread wear.
- Rear axle sideset is a condition where the rear axle assembly has moved straight sideways and the geometric centerline is not positioned at the true vehicle centerline.
- Setback occurs when one front or rear wheel is moved backward in relation to the opposite wheel.
- In a geometric centerline front wheel alignment, the geometric centerline is used for a reference for front wheel toe. This type of alignment ignores thrust line position.
- In a thrust line front wheel alignment, the front wheel toe is checked using the thrust line as a reference, but the thrust line position may not be at the geometric centerline.
- In a total four-wheel alignment, the thrust line position is measured and the rear wheel toe is measured and adjusted as necessary so the thrust line is at the geometric centerline. The front wheel toe is measured using the common thrust line and geometric centerline as a reference.
- Computer alignment systems have a wheel unit mounted on a wheel clamp attached to each rim.
- Signals from the wheel sensors to the computer wheel aligner may be transmitted by a high-frequency transmitter in the wheel sensor.
- Computer alignment systems provide vehicle specifications plus diagrams of adjustment and inspection points.
- Directional stability is the tendency of a vehicle to travel straight ahead without being steered.
- Suspension and steering systems are designed to provide satisfactory vehicle control with acceptable driver effort and road feel and minimal tire tread wear.
- Proper wheel alignment and suspension component condition are extremely important to maintain vehicle driving safety.
- Many road variables such as bumps and holes, road crown, and heavy vehicle loads affect wheel alignment.
- Wheel alignment angles are designed to compensate for road variables.
- Camber is the tilt of a line through the center of the tire and wheel in relation to the vertical centerline of the tire and wheel.
- Positive camber is obtained when the centerline of the tire and wheel is tilted outward in relation to the vertical centerline of the tire and wheel.
- Negative camber is present when the centerline of the tire and wheel is tilted inward in relation to the vertical centerline of the tire and wheel.
- During wheel jounce, the top of the wheel moves outward and the camber becomes more positive.

Terms to Know

Bump steer
Directional stability
Four wheel alignment
Geometric centerline
Geometric centerline alignment

Terms to Know

(continued)

High-frequency transmitter
Jounce
Memory steer
Motorist Assurance Program (MAP)
Negative camber
Negative caster
Positive camber
Positive caster
Rear axle offset
Rear axle sideset
Rebound
Receiver
Road crown
Road variables
Steering drift
Steering pull
Steering wander
Thrust angle
Thrust line
Thrust line alignment
Torque steer
Tracking
Wheel alignment
Wheel sensors
Wheel setback
Wheel shimmy

Summary

- During wheel rebound, the top of the wheel moves inward and the camber becomes less positive or moves to a slightly negative position.
- While cornering at high speeds, centrifugal force attempts to move the vehicle to the outside of the turn. This force raises the front suspension on the inside of the turn while lowering the front suspension on the outside of the turn.
- While cornering at high speeds, the front wheel on the inside of the turn moves to a less positive camber angle, and the camber angle becomes more positive on the outside front wheel.
- Excessive positive or negative camber concentrates the vehicle weight on one side of the front tire. The tire edge on which the weight is concentrated has a smaller diameter compared with the other side of the tire. Since the side of the tire with the smaller diameter makes more revolutions to go the same distance, this side of the tire becomes worn and scuffed.
- A wheel turns in the direction it is tilted.
- Road crown causes the vehicle steering to drift to the right.
- The camber on the left front wheel may be adjusted so it is slightly more positive than the right front wheel camber to compensate for steering pull to the right caused by road crown.
- Caster is the tilt of a line that intersects the center of the lower ball joint and the center of the upper strut mount in relation to a vertical line through the center of the spindle and wheel as viewed from the side.
- Positive caster occurs when the centerline of the lower ball joint and upper strut mount is tilted rearward in relation to the centerline of the spindle and wheel, viewed from the side.
- Negative caster is obtained when the centerline of the lower ball joint and upper strut mount is tilted forward in relation to the centerline of the spindle and wheel.
- Positive caster increases directional stability, steering effort, and steering wheel returning force.
- Excessive positive caster results in harsh ride quality.
- Excessive positive caster may cause front wheel shimmy.
- Negative caster reduces directional stability and steering effort while improving ride quality.
- If the caster is different on the two front wheels, the steering pulls toward the side with the least positive caster.
- The caster adjustment on the left front wheel may be adjusted so it is less positive than the caster on the right front wheel to compensate for road crown.
- If the rear suspension height is lowered, the front wheel caster becomes more positive.
- When the front suspension height is lowered, the front wheel caster becomes more positive.
- Proper caster adjustment is very important to maintain vehicle directional control and safety.

Review Questions

Short Answer Essays

1. Explain why four-wheel alignment is essential on unitized body cars with semi-independent or independent rear suspension.
2. Explain why the front wheels are not placed in the exact vertical position for proper wheel alignment.
3. Describe the camber change during front wheel jounce.
4. Explain the camber change during front wheel rebound.
5. Explain why excessive positive camber wears the outside edge of the tire tread.
6. Explain how the front wheel camber may be adjusted to compensate for road crown.
7. Explain why positive caster provides increased directional stability.

8. Describe how positive caster provides increased steering wheel returning force.
9. Explain why positive caster causes harsh riding quality.
10. Describe how the caster adjustment may be used to compensate for road crown.

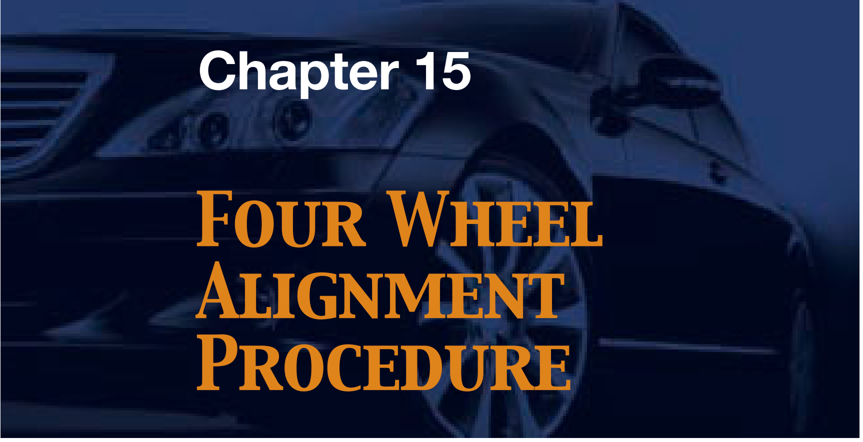
Fill-in-the-Blanks

1. Excessive toe-out on the right rear wheel moves the thrust line to the _______________ of the geometric centerline.
2. If the thrust line is positioned to the left of the geometric centerline so the thrust angle is more than specified, the steering pulls to the _______________.
3. Directional stability refers to the tendency of a vehicle to travel straight ahead without being _______________.
4. When the front wheel camber is negative, the centerline of the tire and wheel is tilted _______________ in relation to the true vertical centerline of the tire and wheel.
5. Excessive negative front wheel camber results in tread wear on _______________ the edge of the front tire.
6. Negative front wheel caster decreases _______________ _______________ and steering wheel _______________ _______________.
7. Raising the rear suspension height above the manufacturer's specification may change the front wheel caster from _______________ to _______________.
8. Front wheel shimmy may be caused by excessive _______________ caster.
9. Front wheel caster becomes more positive if the rear suspension height is _______________.
10. If the front suspension height is lowered on a MacPherson strut suspension, the front wheel caster becomes _______________ _______________.

Multiple Choice

1. While diagnosing the vehicle geometric centerline and thrust line:
   A. The front and rear wheels should be parallel to the geometric centerline.
   B. The thrust angle is the difference between the front wheel camber and SAI angles.
   C. If the thrust angle is more than specified, front wheel shimmy may occur.
   D. A bent front cradle may cause the thrust angle to be more than specified.
2. While diagnosing rear axle offset and sideset:
   A. If the rear axle is offset so the thrust line is moved to the left of the geometric centerline, the steering pulls to the left.
   B. When rear axle sideset occurs, one rear wheel is moved rearward in relation to the opposite rear wheel.
   C. On a semi-independent rear suspension system, worn trailing arm bushings may cause rear axle offset.
   D. On an independent rear suspension system, a worn lower ball joint may cause rear axle offset.
3. A front-wheel-drive vehicle with an independent rear suspension pulls to the right when driving straight ahead. All the front suspension alignment angles are within specifications. The most likely cause of this problem is:
   A. Excessive toe-out on the right rear wheel.
   B. Excessive negative camber on the right rear wheel.
   C. Excessive toe-out on the left rear wheel.
   D. Excessive positive camber on the left rear wheel.
4. All of these statements about the vehicle thrust line and steering pull are true EXCEPT:
   A. Excessive toe-out on the left rear wheel moves the thrust line to the left of the vehicle centerline.
   B. Excessive toe-in on the right-rear wheel moves the thrust line to the right of the vehicle centerline.
   C. If the thrust line is moved to the left of the vehicle centerline, the steering tends to pull to the right.
   D. Excessive toe-out on the right-rear wheel causes the steering to pull to the left.

5. While diagnosing suspension and wheel alignment problems:
   A. Road crown has no effect on vehicle steering or wheel alignment.
   B. Vehicle loads have no effect on wheel alignment.
   C. Steering angles are designed to reduce tire wear and provide directional control.
   D. Wheel alignment angles do not affect riding quality.
6. All of these statements about computer wheel aligners are true EXCEPT:
   A. Some front wheel sensors contain optical sensors for toe measurement and strings connected to the rear wheel sensors.
   B. Vehicle specifications and the alignment program may be stored on CDs.
   C. Digital photos of suspension adjustments and inspection points are available.
   D. Signals from high-frequency transmitters in wheel sensors may be blocked by a steel toolbox.
7. While driving straight ahead, a front-wheel-drive car pulls to the right. The most likely cause of this problem is:
   A. More positive camber on the left front wheel compared to the right front wheel.
   B. Sagged front springs and improper front wheel toe setting.
   C. Less positive caster on the right front wheel compared to the left front wheel.
   D. The SAI on the right front wheel is 1 1/2° more than the SAI on the left front wheel.
8. While adjusting front wheel camber and diagnosing camber-related problems:
   A. During front wheel jounce travel, the positive camber increases.
   B. Excessive positive camber on a front wheel causes premature wear on the inside edge of the tire tread.
   C. If the right front wheel camber is +1 1/2° and the left front camber is +1/2°, the steering pulls to the left.
   D. Excessive positive camber on both front wheels may cause front wheel shimmy.
9. A driver complains of harsh riding and the suspension height is normal. The most likely cause of this problem is:
   A. Excessive negative camber on both front wheels.
   B. Excessive positive caster on both front wheels.
   C. The left front wheel has more positive caster than the right front wheel.
   D. Both front wheels have negative camber and negative caster.
10. Excessive positive caster may cause all of these problems EXCEPT:
   A. Front wheel shimmy.
   B. Harsh ride quality.
   C. Excessive steering effort.
   D. Slow steering wheel return.



Chapter 15

Four Wheel Alignment Procedure

Upon completion and review of this chapter, you should be able to:

- Perform a prealignment inspection.
- Diagnose wheel alignment and tire wear problems.
- Position a vehicle on the alignment rack and connect the wheel units on a computer wheel aligner to the wheel rims.
- Select the specifications in the computer wheel aligner for the vehicle being aligned.
- Perform a preliminary wheel alignment inspection with the preliminary inspection screen.
- Perform a ride height inspection and measurement with the ride height screen.
- Perform an automatic or manual wheel runout compensation procedure.
- Measure front wheel camber and caster.
- Measure front and rear wheel setback.
- Measure steering axis inclination (SAI).
- Measure front wheel toe and turning radius.
- Measure toe change during front wheel jounce and rebound to check steering linkage height.
- Diagnose bent front struts.
- Recognize the symptoms of improper rear wheel alignment.
- Measure rear wheel camber and toe.

Wheel Alignment Preliminary Diagnosis and Inspection

Customer Complaints Related to Suspension or Brakes

Drivers may experience a variety of symptoms related to incorrect wheel alignment or defective brakes (Figure 15-1). Not all the symptoms are related to wheel alignment, but the customer may request an alignment to correct these problems. The technician must diagnose and correct the cause of the specific complaint. Wheel alignment angles that affect tire wear are toe and camber. The most likely symptoms of incorrect toe or camber settings are pull to one side while driving, wander, feathered tire wear, or tire wear on one side.

BASIC TOOLS

Basic technician's tool set

Service manual

Road Test

In many cases, a **road test** is necessary to verify customer complaints. During a road test, the vehicle should be driven under the conditions when the customer complaint occurred. While road-testing the vehicle, the technician should listen for any unusual noises related to suspension and steering.

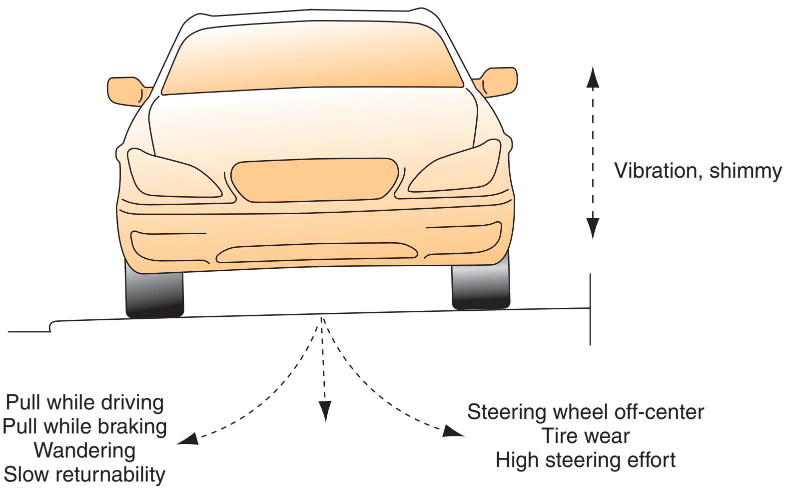


FIGURE 15-1 **Customer complaints related to wheel alignment or brakes.**

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Memory steer occurs when the steering does not want to steer straight ahead after a turn because the steering does not return to the straight-ahead position.

The technician should check for these steering problems during a road test:

1. Excessive vertical chassis oscillations
2. Chassis waddle
3. Steering wander, pull, or drift
4. High steering effort and binding
5. Tire squeal while cornering
6. Bump steer
7. Torque steer
8. Excessive steering wheel free play
9. Suspension bottoming on rough road surfaces
10. Wheel hop during hard acceleration
11. Nose dive while braking or rear suspension squat when accelerating
12. Excessive body sway when cornering
13. Memory steer
14. Steering wheel return

Chassis waddle may be caused by excessive tire or wheel runout. Excessive vertical chassis oscillations are the result of defective shock absorbers or struts. (Refer to Chapter 4 for tire and wheel runout diagnosis and Chapter 5 for shock absorber and strut diagnosis.)

Most steering systems are designed so the steering wheel returns to within 30° to 60° of center after a 180° turn (Figure 15-2). If the steering wheel returnability is not satisfactory and **memory steer** is evident, the steering shaft dash seal or the steering shaft universal

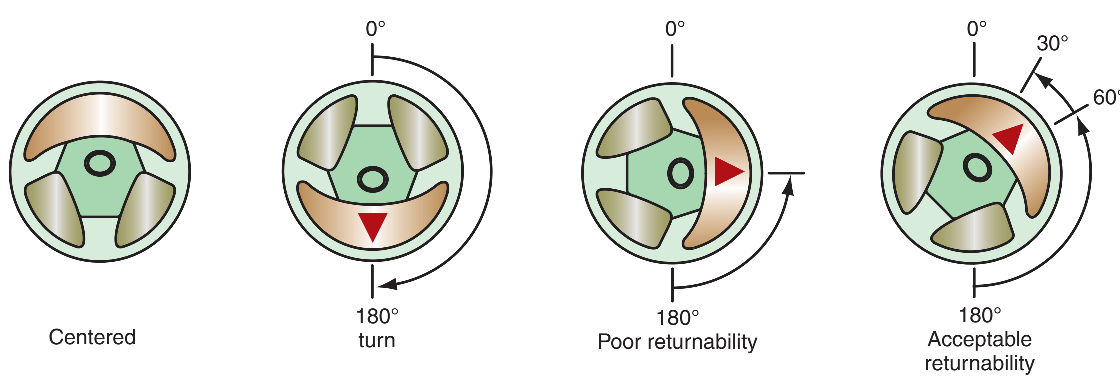


FIGURE 15-2 **Steering wheel returnability.**

joints may be binding. When memory steer occurs on a front-wheel-drive car, the upper strut mounts may be binding. High steering effort, or binding, can also be caused by a loose power steering belt, low power steering fluid level, worn front tires, or a defective steering gear.

A front-wheel-drive vehicle with unequal drive axles produces some **torque steer** on hard acceleration. Some front-wheel-drive vehicles, especially those with higher horsepower, have equal front drive axles to reduce torque steer. On a front-wheel-drive vehicle, torque steer is aggravated by different tire tread designs on the front tires or uneven wear on the front tires. Torque steer may also be aggravated by worn and sagged transaxle and engine mounts that cause improper drive axle angles.

Bump steer occurs if the tie-rods are not the same height, meaning one of the tie-rods is not parallel to the lower control arm. This condition may be caused by a bent or worn idler arm or pitman arm on a parallelogram steering linkage. On a rack and pinion steering system, worn steering gear mounting bushings may cause this unparallel condition between one of the tie-rods and the lower control arm.

Steering pull may be caused by improper caster or camber adjustments.

During a road test, any of the following symptoms may indicate improper rear wheel alignment:

1. The front wheel **toe-in** is set correctly with the steering wheel centered on the alignment rack, but the steering wheel is not centered when the vehicle is driven straight ahead.
2. When there are no worn suspension parts or defective tires and all front suspension angles are within specifications, but the vehicle wanders or drifts to one side.
3. The vehicle is not overloaded, all front suspension angles are within specifications, and there are no worn suspension parts, but tire wear recurs.

Prealignment Inspection

The technician should identify the exact suspension or steering complaint before a wheel alignment or other suspension work is performed. The technician must diagnose the cause or causes of the complaint and correct this problem during the wheel alignment (Figure 15-3). Since collision damage may affect wheel alignment angles, an inspection for collision damage on the vehicle should be completed prior to a wheel alignment (Figure 15-4).

Worn suspension and steering components must be replaced before a wheel alignment is performed. A wheel alignment should be performed after suspension components such as struts have been replaced.

The following components and measurements should be checked in a prealignment inspection:

1. Curb weight
2. Tires
3. Suspension height
4. Steering wheel free play
5. Shock absorbers or struts
6. Wheel bearing adjustment
7. Ball joint condition
8. Control arms and bushings
9. Steering linkages and tie-rod ends
10. Stabilizers and bushings
11. Full fuel tank

Components to be checked in a **prealignment inspection** and wheel alignment measurements are summarized in Figure 15-5.

These checks should be completed with the car on the floor:

Torque steer is the tendency of the steering to pull to one side during hard acceleration.

Bump steer is the tendency of the steering to veer suddenly in one direction when one or both front wheels strikes a bump.

SERVICE TIP:
If steering pull or drift is evident during the road test, drive the vehicle on the same road in the opposite direction to determine if a crosswind is causing the steering pull.

Toe-in occurs when the distance between the front edges of the front or rear tires is less than the distance between the rear edges of the tires.

Worn suspension and steering components must be replaced before a wheel alignment is performed.

After suspension components such as struts have been replaced, a wheel alignment should be performed.

Condition	Probable Cause
Tire wear:	
Outer shoulder	Too much positive camber
Inner shoulder	Too much negative camber
Sawtooth pattern:	
Sharp edge towards center	Too little toe-in
Sharp edge away from center	Too much toe-in
Both shoulders	Underinflation, high-speed cornering, overloading
Tread roll under	High speed in curves
Cupping, dishing	Wheel imbalance, radial runout
Diagonal wipe	Incorrect rear toe FWD Vehicle
Shimmy:	
With or without vehicle instability	Too much positive caster, unequal caster between wheels
Without instability	Tire imbalance, tire runout, driveline vibration
Vibration: (Caster/camber not a probable cause. The condition is listed because it is sometimes misdiagnosed as shimmy.)	Driveline misalignment, driveline imbalance, vehicle shake (accompanied by a characteristic moan), tire runout, unequal weight distribution between wheels
Steering wander/pull	Incorrect camber Unequal caster Overload, which elevates front end
Brake pull	Too much negative caster Unequal tire pressure, brake line damage that impedes hydraulic action on one side
Hard steering	Incorrect caster Damaged steering linkage, worn steering linkage, damaged spindles, rear-end overload, bent steering arm causing incorrect turning angle

FIGURE 15-3 **Diagnosis of wheel alignment problems.**

1. Inspect for excessive mud adhered to the chassis. Remove heavy items from the trunk and passenger compartment that are not considered in the vehicle curb weight. If heavy items such as tool display cases or merchandise are normally carried in the vehicle, these items should be left in the car during a wheel alignment.

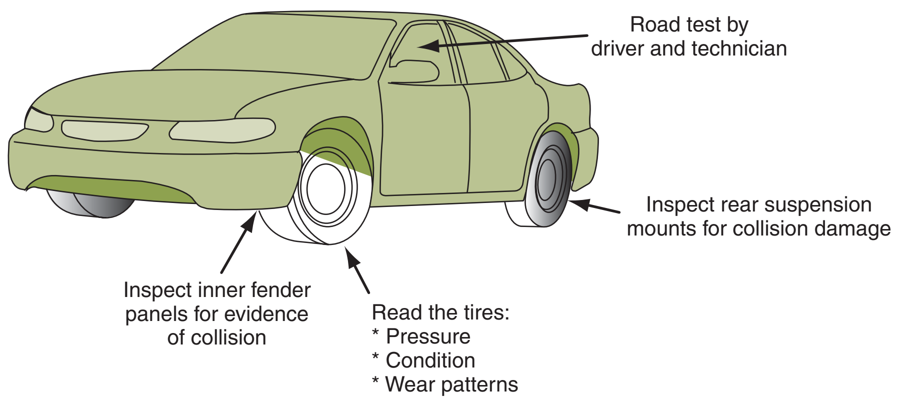


FIGURE 15-4 **Collision damage inspection.**

2. Inflate tires to the recommended pressure and note any abnormal tread wear ordamage on each tire. Be sure all tires are the same size.
3. Check the front tires and wheels for radial runout. (Refer to Chapter 4 for this measurement.)
4. Check the suspension **ride height.** If this measurement is not within specifications, check for broken or sagged springs. On a torsion bar suspension system, check the torsion bar adjustment.
5. Inspect front and rear suspension bumpers. Worn bumpers may indicate weak springs or worn-out shock absorbers or struts.
6. When the wheels are in the straight-ahead position, rotate the steering wheel back and forth to check for play in the steering column, steering gear, or linkages.
7. Inspect the shock absorbers or struts for loose mounting bushings and bolts. Examine each shock absorber or strut for leakage.
8. Inspect the condition of each shock absorber or strut with a bounce test at eachcorner of the vehicle. (This test is explained in Chapter 5.)

A **prealignment inspection** of all steering and suspension components must be completed before a wheel alignment procedure.

SERVICE TIP: Decreasing the rear ride height 1 in. (25.4 mm) moves the front wheel caster 1° more positive.

The following checks should be performed with the vehicle raised and the suspension supported:

1. Inspect the front wheel bearings for lateral movement. (This inspection is described in Chapter 3.) On front-wheel-drive vehicles, perform this inspection on all four wheel bearings. Wheel bearings must be properly adjusted prior to a wheel alignment. Clean, repack, or adjust the wheel bearings as necessary.
2. Measure the ball joint radial and axial movement. If excessive movement exists in either direction, ball joint replacement is required. (Ball joint diagnosis and replacement is explained in Chapter 6.) Be sure the suspension is supported correctly during ball joint diagnosis.
3. Inspect the control arms for damage and inspect the control arm bushings for wear.
4. Inspect all the steering linkages and tie-rod ends for looseness.
5. Inspect for worn stabilizer mounting links and bushings.
6. Inspect for loose steering gear mounting bolts and worn mounting brackets and bushings.

Ride height is the distance from a specified location on the front or rear suspension to the road surface.

Tire Wear Diagnosis

Various types of tire tread wear patterns indicate specific alignment or balance defects (Figure 15-6).

Improper camber settings cause wear on one side of the front tire treads.

PREALIGNMENT INSPECTION CHECKLIST

Owner ______________________ Phone ______________ Date ___________

Address ______________________________ VIN ______________________

Make __________ Model __________ Year ______ Lic. number ____________ Mileage ____________

1. Road test results	Yes	No	Right	Left
Above 30 MPH				
Below 30 MPH				
Bump steer				
When braking				
Steering wheel movement Stopping from 2 to 3 MPH(Front)				
Vehicle steers hard				
Strg wheel returnability normal				
Strg wheel position				
Vibration	Yes	No	Frnt	Rear

2. Tire pressure Specs Frnt ____ Rear ____

Record pressure found

RF ______ LF ________ RR ________ LR ________

3. Chassis height Specs Frnt ____ Rear ____

Record height found

RF ______ LF ________ RR ________ LR ________

	Yes	No
Springs sagged		
Torsion bars adjusted		

4. Rubber bushings	OK
Upper control arm	
Lower control arm	
Sway bar / stabilizer link	
Strut rod	
Rear bushing	

5. Shock absorbers/struts	Frnt	Rear

6. Steering linkage	Frnt OK	Rear OK
Tie-rod ends		
Idler arm		
Center link		
Sector shaft		
Pitman arm		
Gearbox/rack adjustment		
Gearbox/rack mounting		

7. Ball joints	OK
Load bearings	
Specs: Right _____ Left _____ / Readings: Right _____ Left _____	
Follower	
Upper strut bearing mount	
Rear	

8. Power steering	OK
Belt tension	
Fluid level	
Leaks/hose fittings	
Spool valve centered	

9. Tires/wheels	OK
Wheel runout	
Condition	
Equal tread depth	
Wheel bearing	

10. Brakes operating properly	

11. Alignment	Spec		Initial reading		Adjusted reading	
	R	L	R	L	R	L
Camber						
Caster						
Toe						

Bump steer	Toe change right wheel		Toe change left wheel	
	Amount	Direction	Amount	Direction
Chassis down 3"				
Chassis up 3"				

	Spec		Initial reading		Adjusted reading	
	R	L	R	L	R	L
Toe-out on turns						
SAI						
Rear camber						
Rear total toe						
Rear indiv. toe						
Wheel balance						
Radial tire pull						

FIGURE 15-5 **Prealignment inspection and wheel alignment checklist.**

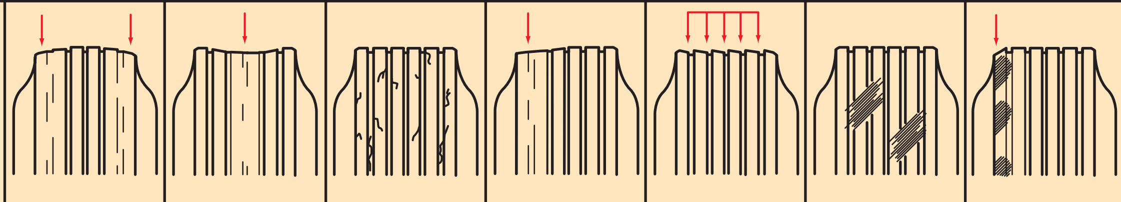
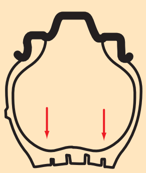
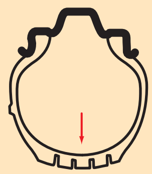
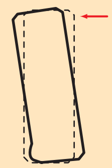
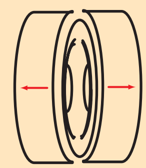
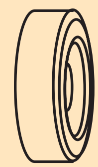
Conditions	Rapid wear at shoulders	Rapid wear at center	Cracked treads	Wear on one edge	Feathered edge	Diagonal wipe rear tire FWD vehicles	Scalloped wear
Effect							
Causes	Underinflation or lack of rotation 	Overinflation or lack of rotation 	Underinflation or excessive speed	Excessive camber 	Incorrect toe 	Incorrect wheel toe 	Lack of rotation of tires or worn or out-of-alignment suspension
Corrections	Adjust pressure to specifications when tires are cool. Rotate tires.			Adjust camber to specs	Adjust toe to specs	Perform rear wheel alignment	Rotate tires and inspect suspension

FIGURE 15-6 **Tire tread wear patterns and causes.**

Four Wheel Alignment with Computer Alignment Systems

Preliminary Procedure

WARNING: When using a computer wheel aligner, always follow the equipment manufacturer's recommended procedures to provide accurate readings and to avoid equipment and vehicle damage or personal injury.

The vehicle should be on an **alignment ramp** with a **turntable** under each front tire and conventional **slip plates** under the rear tires (Figure 15-7). Slip plates under the rear tires allow unrestricted movement of the rear wheels during rear wheel camber and toe adjustments (Figure 15-8). If suspension adjustments are made with the tires contacting the alignment ramp or the shop floor, the tires cannot move when the adjustment is completed. This action causes inaccurate suspension adjustments. The center of the front wheel spindles should be in line with the zero mark on the turning plates. The locking pins must be left in these plates and the parking brake applied.

Mount the **rim clamps** on each wheel. It may be necessary to remove the chrome discs or hub caps before these clamps can be installed. The adjustment knob on the rim clamp should be pointing toward the top of the wheel, and the bubble on the wheel unit should be centered (Figure 15-9). A set knob on the wheel unit allows the service technician to lock the wheel unit in this position. Some computer wheel aligners have a display on the monitor that indicates if any of the wheel sensors are not level (Figure 15-10). These sensors may be leveled by pressing a control knob on each wheel sensor. Some **digital signal processor (DSP)** wheel sensors contain a microprocessor and a **high-frequency transmitter** that acquire measurements and process data and then send these data to a **receiver** mounted on top of

An **alignment ramp** is a special steel ramp on which the vehicle is positioned for a wheel alignment.

SPECIAL TOOLS

Computer wheel aligner

A **turntable** is placed under each front wheel during a wheel alignment. The turntables allow the wheels to turn, and they also allow the wheels to move during alignment adjustments.

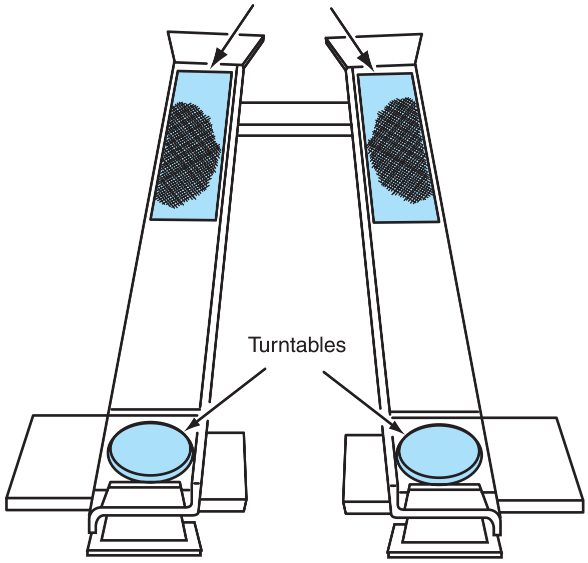


FIGURE 15-7 **Alignment ramp with turntables.**

Slip plates under the rear wheels allow the wheels to move during alignment adjustments.

FIGURE 15-8 **Rear wheel slip plates. (Courtesy of Snap-On Tools Corp.)**

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Rim clamps mount each wheel sensor to the rim.

A **digital signal processor (DSP)** in each wheel sensor provides digital signals indicating wheel alignment angles.

A **high-frequency transmitter** in each wheel sensor processes data from the DSP and transmits this data to the computer wheel aligner.

the wheel alignment monitor. This type of wheel sensor does not require any cables connected between the sensors and the computer wheel aligner. The data from this type of wheel sensor signal are virtually uninterruptible, even by solid objects. When these wheel sensors are stored on the computer wheel aligner, a "docking station" feature charges the batteries in the wheel sensors.

Some wheel sensors contain infrared emitter/detectors or light-emitting diodes (LEDs) between the front and rear wheel sensors to perform alignment measurements. Older wheel sensors have strings between the front and rear wheel sensors. Each wheel sensor contains a microprocessor with a preheat circuit that stabilizes the readings in relation to temperature. Some wheel sensors have touch keypads on the wheel units to allow the entry of commands from each unit. The front wheel units have arms that project toward the front of the vehicle to transmit signals between these units. When a blocked beam prompt appears on any screen,

FIGURE 15-9 **Rim clamp and wheel sensor.**

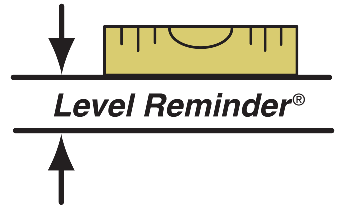

FIGURE 15-10 **Wheel sensor level indicator on the monitor screen.**

the beam between two wheel units is blocked. This could be caused by a person standing in the beam, an open car door, or a suspension jack. The blocked beam prompt must be eliminated before any tests are completed.

The manufacturers of various types of computer alignment systems publish detailed operator's manuals for their specific equipment. Our objective here is to discuss some of the general screens that a technician uses while measuring wheel alignment angles with a typical computer aligner.

A **receiver** mounted on or in the computer wheel aligner receives data from the high-frequency transmitters in the wheel sensors.

Main Menu

One of the first items displayed on the computer aligner screen is the **main menu** screen. From this screen, the technician makes a selection by touching the desired selection on the monitor screen with a mouse (Figure 15-11) or by pressing the number on the keypad that matches the number beside the desired procedure. A cursor may also be used to select the type of alignment.

FIGURE 15-11 **Making screen selections with a mouse.**

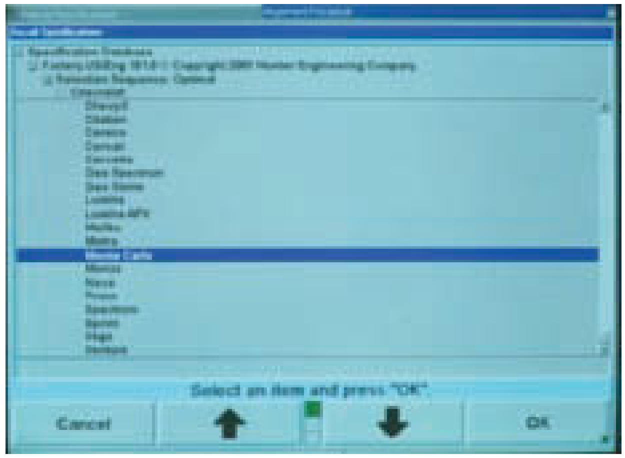

FIGURE 15-12 **Entering vehicle specifications.**

Specifications Menu

Some computer wheel aligners have specifications contained on CDs. The appropriate CD must be placed in the aligner. Several methods may be used to enter the vehicle specifications. The technician may scroll through the **specifications menu** and then press Enter when the appropriate vehicle is highlighted on the screen (Figure 15-12). The technician may also select the proper vehicle specifications by pointing with the light pen or by typing in the vehicle identification number (VIN) or the first letter in the vehicle make.

On other computer wheel aligners, the specifications are contained on a floppy disk and the technician selects the appropriate make, model, and year of vehicle with the cursor on the screen.

On early computer alignment systems, the vehicle specifications were contained on bar graphs. The technician moved a wand across the appropriate bar graph to enter the specifications for the vehicle being aligned.

Preliminary Inspection Screen

The **preliminary inspection screen** allows the technician to enter the condition of all front and rear suspension components that must be checked during a prealignment inspection. On some computer alignment systems, the technician may enter checked, marginal, and repair or replace for each component (Figure 15-13). These entered conditions may be printed out at any time or with the complete wheel alignment results.

FIGURE 15-13 **Preliminary inspection screen.**

Ride Height Screen

Some computer wheel aligners have optical encoders in the wheel sensors that measure ride height when this selection is displayed on the screen and the ride height attachment on each wheel sensor is lifted until it touches the lower edge of the fender (Figure 15-14). The ride height measurement is displayed on the screen. If the screen display is green, the ride height is within specifications. A red ride height display indicates this measurement is not within specifications. Improper ride height may be caused by sagged or broken springs, bent components such as control arms, or worn components such as control arm bushings.

Some computer wheel aligners provide a **ride height screen** with a graphic display indicating the exact location where the ride height should be measured (Figure 15-15). The computer aligner compares the ride height measurements entered by the technician to the specifications.

CAUTION:
The ride height must be within specifications before proceeding with the wheel alignment. Improper curb riding height affects many of the other suspension angles.

Tire Condition Screen

When the **tire inspection screen** is displayed, the technician may enter various tire wear conditions for each tire (Figure 15-16). The cursor on the screen is moved to the tire being inspected. The tire conditions are printed out with the preliminary inspection results and

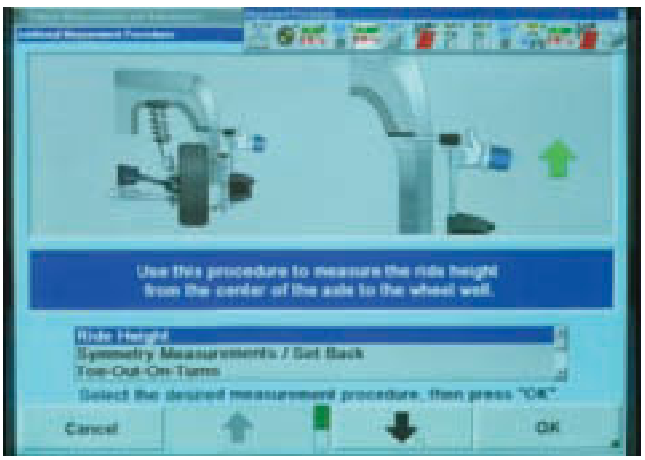

FIGURE 15-14 **Ride height screen and ride height attachment in wheel sensor.**

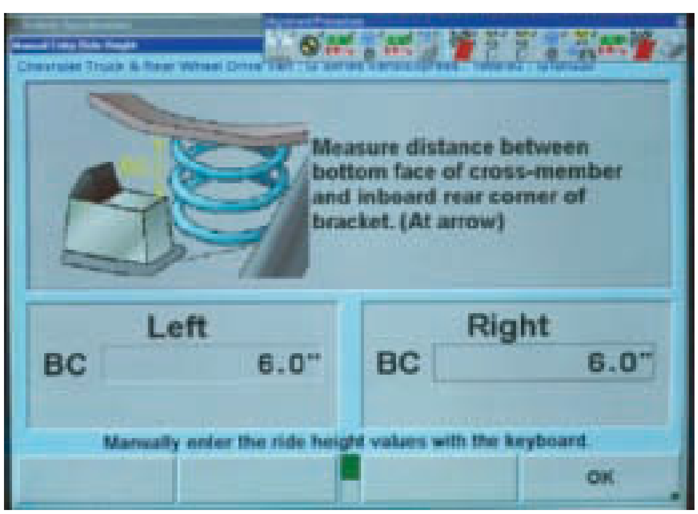

FIGURE 15-15 **Ride height screen.**

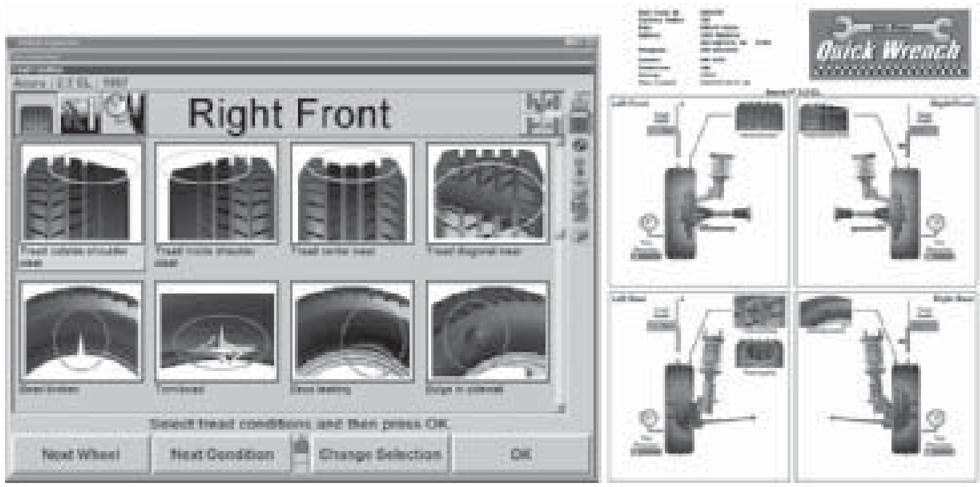

FIGURE 15-16 **Tire inspection screen.**

the alignment report. On other computer wheel aligners, tire condition is included in the preliminary inspection screens.

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Wheel Runout Compensation

As mentioned previously, screen indicators on some computer wheel aligners inform the technician if any of the wheel sensors require leveling or compensating for wheel runout. Runout compensation is accomplished by pressing the appropriate button on each wheel sensor. Some wheel sensors provide continuous compensation. This feature provides accurate alignment angles even when a wheel is rotated after the compensation button on the wheel sensor has been pressed. When the wheel runout screen is displayed, the technician is directed to level and lock each wheel unit and then press the compensation button on each wheel sensor to provide automatic wheel runout compensation (Figure 15-17).

If the computer aligner does not have automatic wheel runout compensation, a manual wheel runout procedure must be followed. This type of computer aligner displays a wheel

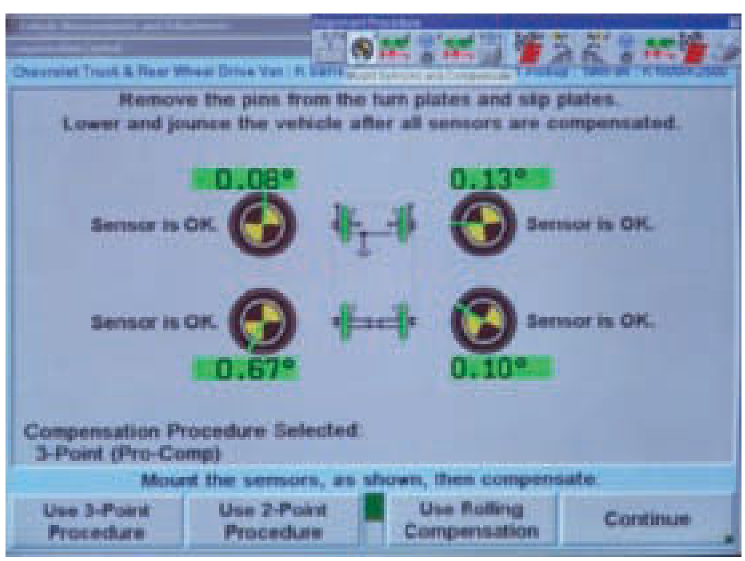


FIGURE 15-17 **Wheel runout compensation screen.**

runout measurement screen. During this procedure, the wheel being checked for runout is lifted with the hydraulic jack on the alignment rack and the wheel is rotated until the rim clamp knob faces downward. Level and lock the wheel unit in this position; then push Yes on the wheel unit as instructed on the screen. Rotate the wheel until the rim clamp knob faces upward; then level and lock the wheel unit. After this procedure, press Yes on the wheel unit. This same basic procedure is followed at each wheel.

SERVICE TIP: Many computer wheel aligners can print out any single screen. It may be helpful to print out the wheel alignment angle screen before and after the alignment angles are adjusted to the vehicle manufacturer's specifications. These printouts may be presented to the customer; many customers appreciate this service.

Wheel Alignment Screens

Front and Rear Wheel Alignment Angle Screen

Prior to a display of the **front and rear wheel alignment angle screen** on some computer wheel aligners, the screen display directs the technician to position the front wheels straight ahead, lock the steering wheel, apply the **brake pedal depressor,** and level and lock the wheel units. See Photo Sequence 27. The brake pedal depressor is an adjustable rod installed between the front edge of the front seat and the brake pedal (Figure 15-18). If the vehicle has power brakes, the engine should be running when the depressor is used to apply the brakes. Some steering wheel holders are installed between the steering wheel and the top of the front seat (Figure 15-19). A ratchet and handle on the steering wheel holder allow extension of this holder.

After the wheel runout compensation procedure is completed at each wheel sensor, some computer wheel aligners automatically display **camber**, toe-in or **toe-out**, **total toe**,

Camber is the tilt of a line through the tire and wheel centerline in relation to the true vertical centerline of the tire and wheel.

Toe-out is present when the distance between the front edges of the front or rear wheels is more than the distance between the rear edges of the front or rear wheels.

Total toe is the sum of the toe settings on the front wheels.

FIGURE 15-18 **Brake pedal depressor.**

FIGURE 15-19 **Steering wheel holder.**

PHOTO SEQUENCE 27

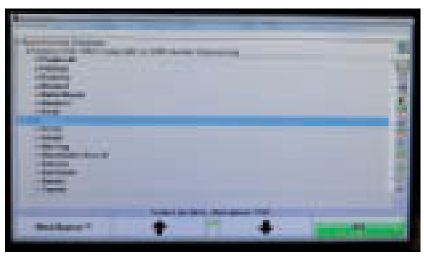
Typical Procedure for Performing Four-Wheel Alignment with a Computer Wheel Aligner

P27-1 **Position the vehicle on the alignment ramp.**

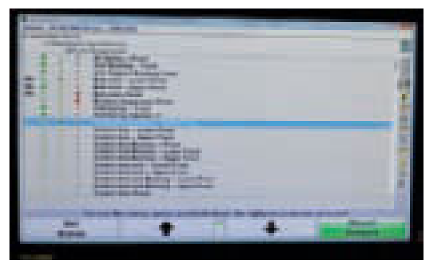
P27-2 **Be sure the front tires are positioned properly on the turntables.**

P27-3 **Position the rear wheels on slip plates.**

P27-4 **Attach the wheel units.**



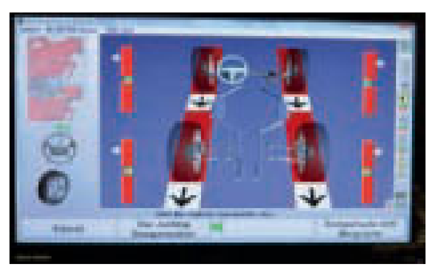
P27-5 **Select the vehicle make and model year.**



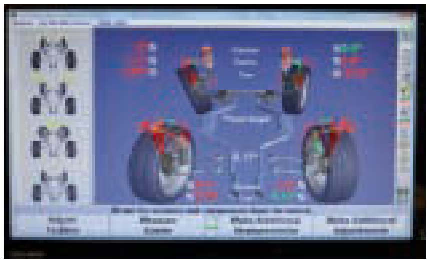
P27-6 **Check items on the screen during preliminary inspection.**

P27-7 **Display the ride height screen.**

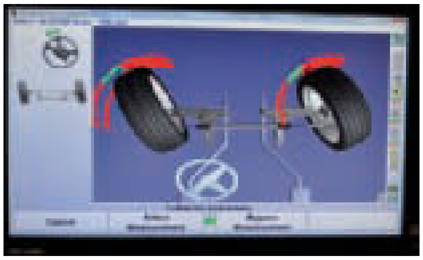
P27-8 **Check the tire condition for each tire on the tire condition screen.**



P27-9 **Display the wheel runout compensation screen.**



P27-10 **Display the front and rear wheel alignment angle screen.**



P27-11 **Display the turning angle screen and perform the turning angle check.**

P27-12 **Display the adjustment screens.**

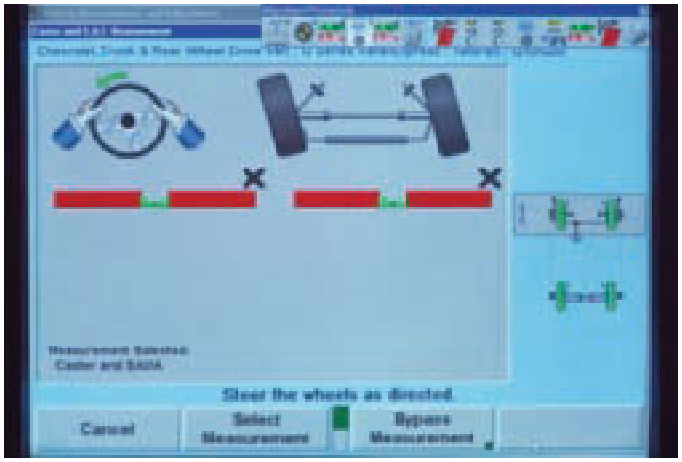


FIGURE 15-20 **Wheel swing instructions on the screen.**

Setback is the distance that one front or rear wheel is moved rearward in relation to the opposite front or rear wheel.

The **thrust line** is positioned at 90° in relation to the rear axle, and this line projects forward.

Caster is the tilt of a line through the centers of the lower ball joint and upper strut mount in relation to a vertical line through the center of the wheel and spindle as viewed from the side.

The **steering axis inclination (SAI)** line is an imaginary line through the centers of the upper and lower ball joints or through the center of the lower ball joint and the upper strut mount.

setback, and **thrust line** measurements on the front and rear suspension. After this procedure, the screen directs the technician to swing the front wheels outward a specific amount (Figure 15-20). The steering wheel holder must be released and the lock pins removed from the front turntables before the wheel swing procedure. This front wheel swing may be referred to as a caster/SAI swing. The amount of front wheel swing varies depending on the make of the computer aligner. Older computer wheel aligners required the technician to read the degrees of wheel swing on the turntable degree scales. On some newer computer wheel aligners, the required amount of wheel swing is illustrated on the screen (Figure 15-21).

After the front wheel swing procedure, all the front and rear wheel alignment angles are displayed, including **caster, steering axis inclination (SAI),** and **included angle** (Figure 15-22). Some computer wheel aligners highlight any wheel alignment angles that are not within specifications. If cross camber and cross caster are displayed on the screen, these readings indicate the maximum difference allowed between the right and left side readings. Alignment angles within specifications are highlighted in green; alignment angles that are not within specifications are highlighted in red.

FIGURE 15-21 **Wheel swing procedure illustrated on the screen.**

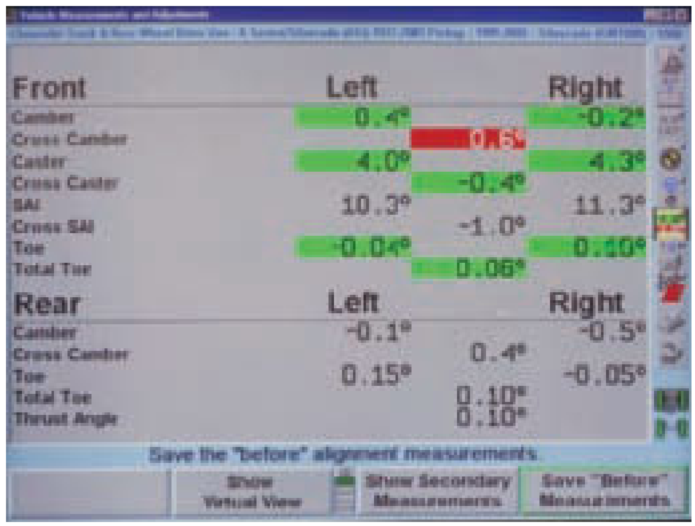


FIGURE 15-22 **Front and rear wheel alignment screen.**

The SAI angle is the angle between the SAI line and the true vertical centerline of the tire and wheel.

Turning Angle Screen

Some computer wheel aligners have a turning angle screen. When this screen is displayed, the technician removes the locking pins from the turntables. Each front wheel must be turned outward a specified amount, and the turning angle on the opposite front wheel must be entered with the keypad as directed on the screen (Figure 15-23). A toe-out on turns option is available on some DSP wheel sensors. This option has optical encoders in the wheel sensors that measure the turning angle electronically rather than reading the degree scales on the front turntables. Photo Sequence 28 shows a manual procedure for measuring turning angle.

The **included angle** is the sum of the SAI angle and the camber angle if the camber is positive. If the camber is negative, the camber setting must be subtracted from the SAI angle to obtain the included angle.

WinAlign 10.0 Software with Advanced Vehicle Handling (AVH)

Advanced vehicle handling (AVH) is a standard feature of WinAlign 10.0 computer alignment software. AVH allows the technician to locate the cause of hidden suspension, chassis, and body problems prior to alignment adjustments. All chassis and suspension components should be inspected during the preliminary alignment inspection, and any worn or defective components must be replaced prior to using the AVH alignment software. AVH measurements include the following:

1. **Caster offset** – Caster offset is the distance from the caster line to the center of the front spindle (Figure 15-24). Caster offset may be called **caster trail**. Assuming the right and

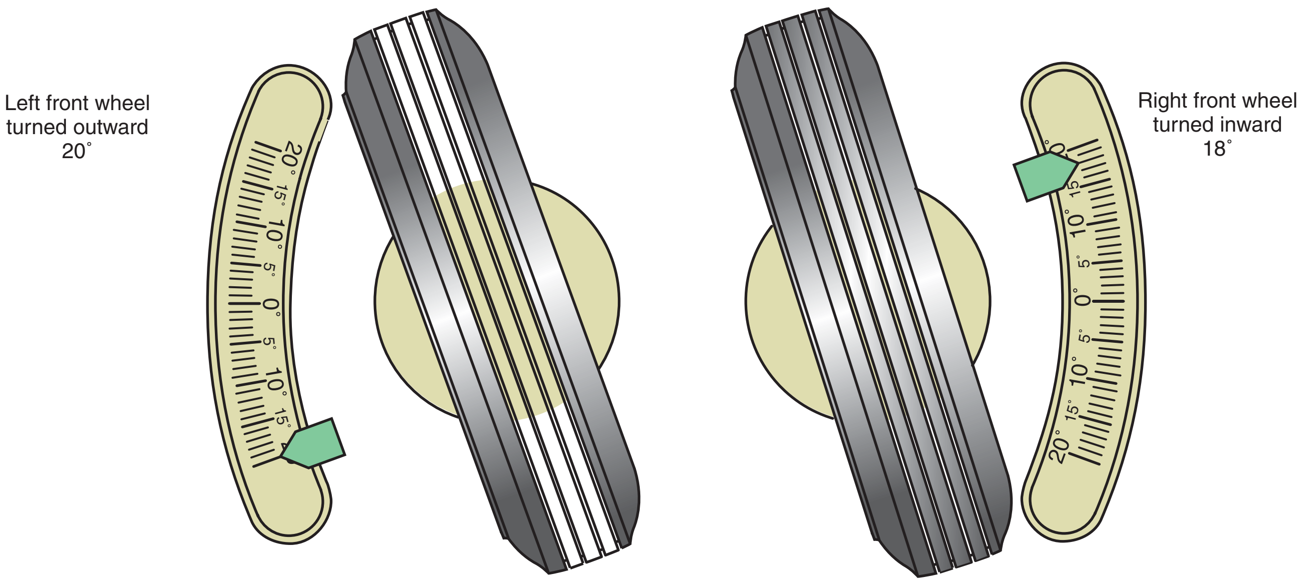


FIGURE 15-23 **Turning angle screen.**

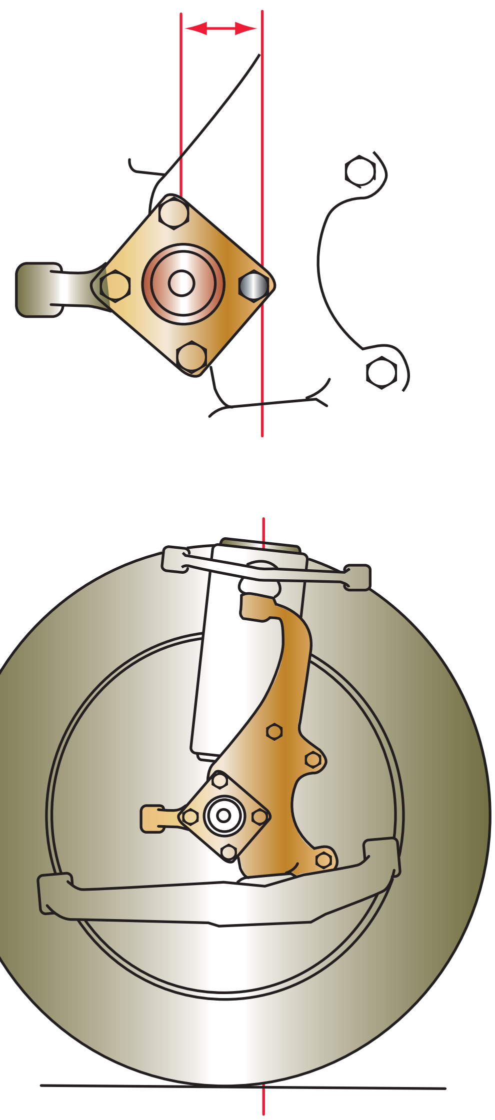


FIGURE 15-24 **Caster offset measurement.**

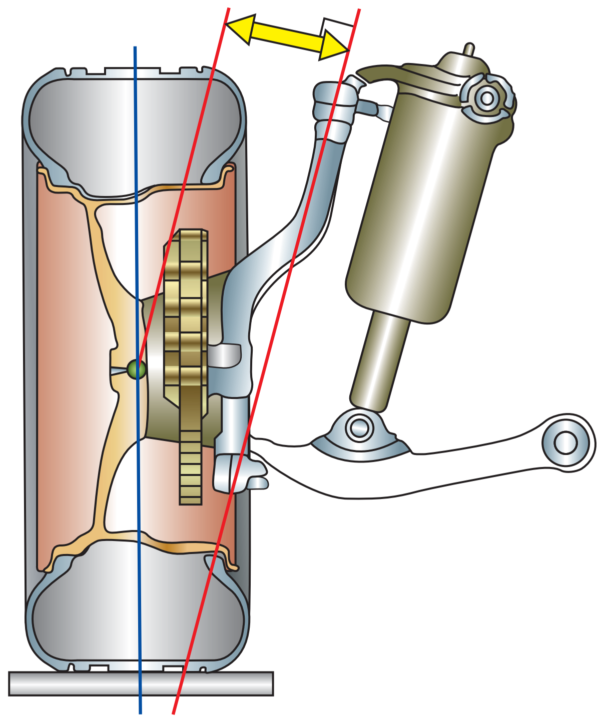


FIGURE 15-25 **Rolling force lever measurement.**

left caster angles are equal, if the right and left caster offset measurements are not equal, suspension components such as the strut or spindle may be worn or bent. Unequal caster offset may cause steering pull or drift.

2. Rolling force lever geometry – The rolling force lever distance is measured from the caster line viewed from the front or rear to a line parallel to the caster line and intersecting the outer end of the spindle (Figure 15-25). If the left and right rolling force lever measurements are unequal, steering pull or drift may occur. Assuming that all suspension and steering components are satisfactory, if the left and right rolling force lever measurements are not equal, one of the spindles is likely bent.
3. Body centerline angle and body centerline offset – Body centerline angle and offset isolates body and chassis centerline. Body centerline and/or body centerline offset problems may indicate collision damage that has not been properly corrected.
4. Body overhang – Body overhang indicates unequal left and right body overhang which usually indicates worn or damaged body mounts or collision damage.
5. Excessive body roll angle when vehicle is steered – This usually indicates defective or worn suspension components such as the stabilizer bar and related parts.
6. Track circle and curb-to-curb distance measurements – If these measurements are not correct, suspension components such as control arms may be defective or bent.
7. Bump steer – Measures suspension angles in relation to suspension movement.

AVH alignment software enables the technician to find the cause(s) of steering problems such as unusual pull complaints including steering pull while braking, excessive torque steer, and bump steer. Locating and correcting the root cause of these problems eliminates steering related comebacks.

Adjustment Screens

The technician may select adjustment screens that provide bar graph readings of camber, caster, and toe. An arrow on the bar graph shows the amount and direction the actual measurement is from the preferred specification. As the alignment angle is adjusted, the arrow moves. If an alignment angle moves from out of the specification range to within the specification

PHOTO SEQUENCE 28

Typical Procedure for Front Wheel Turning Radius Measurement

P28-1 **Perform a prealignment inspection.**

P28-2 **Measure and adjust the other front and rear suspension angles.**

P28-3 **Be sure the front wheels are centered on the turntables and the brake pedal jack is installed to apply the brakes.**

P28-4 **Remove the turntable locking pins and be sure the turning radius gauges are in the zero position with the front wheels straight ahead.**

P28-5 **Turn the right front wheel inward toward the center of the vehicle until the turning radius gauge indicates 20°.**

P28-6 **With the front wheels positioned as described in step 5, read and record the reading on the left turning radius gauge. The reading on the left turning radius gauge should be 22°, or 2° more than the reading on the right turning radius gauge.**

P28-7 **Turn the left front wheel inward toward the center of the vehicle until the turning radius gauge indicates 20°.**

P28-8 **With the front wheels positioned as described in step 7, read and record the reading on the right turning radius gauge. The reading on the right turning radius gauge should be 22°, or 2° more than the reading on the left turning radius gauge.**

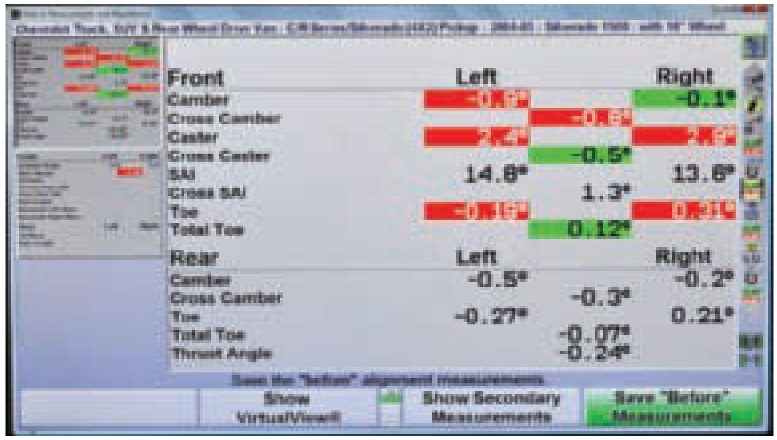


FIGURE 15-26 **Alignment angle adjustment screens.**

range, the bar graph color changes from red to green (Figure 15-26). When the arrow on the bar graph is in the zero position, the alignment angle is at the preferred specification. A zoom feature on some computer wheel aligners provides enlarged bar graphs so they may be seen at a distance while performing the actual suspension adjustments (Figure 15-27). Some computer aligners have a jack and hold feature that allows the suspension to be lifted on the alignment rack to perform an adjustment while maintaining accurate displays on the adjustment screen. Other computer wheel aligners have a remote display that may be connected to the aligner and taken under the car for close-up viewing while performing suspension adjustments (Figure 15-28). The remote display duplicates the bar graphs shown on the monitor screen.

Axle offset occurs when the rear axle is rotated so it is no longer at a 90° angle to the vehicle centerline.

Lateral axle sideset occurs when the rear axle moves inward or outward in relation to the vehicle centerline, but the axle and vehicle centerline remain at a 90° angle.

Some computer wheel aligners provide **symmetry angle measurements** that help the technician determine if out-of-specification readings may have been caused by collision or frame damage. These symmetry angle measurements display **axle offset,** right or left **lateral axle sideset** and track-width difference, front and rear wheel setback, and wheelbase difference (Figure 15-29). Setback is an angle formed by a line drawn at a 90° angle to the centerline and a line connecting the centers of the front or rear wheels (Figure 15-30). Wheelbase difference is an angle created by a line through the rear wheel centers and a line through the front wheel centers (Figure 15-31). Right or left lateral offset is an angle between the thrust line and a line connecting the centers of the left front and left rear wheels or right front and right rear wheels (Figure 15-32). Track-width difference is an angle created by the line

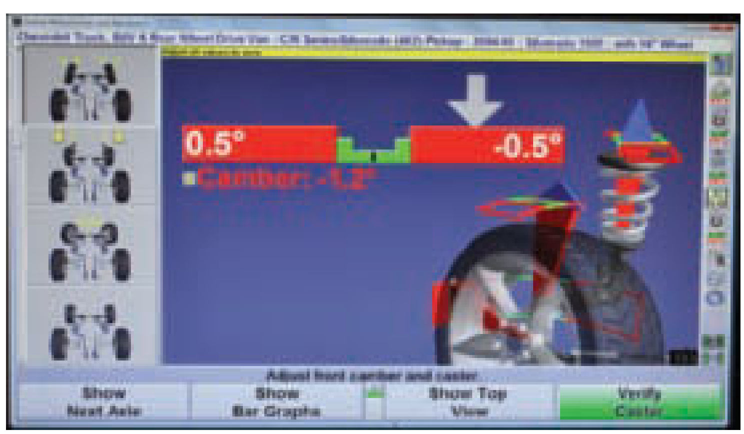


FIGURE 15-27 **Zoom feature on adjustment screens.**

FIGURE 15-28 **Remote display for computer wheel aligner.**

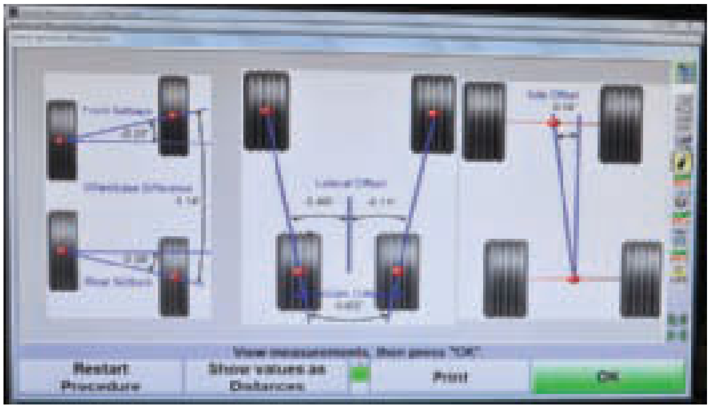


FIGURE 15-29 **Symmetry angle measurements.**

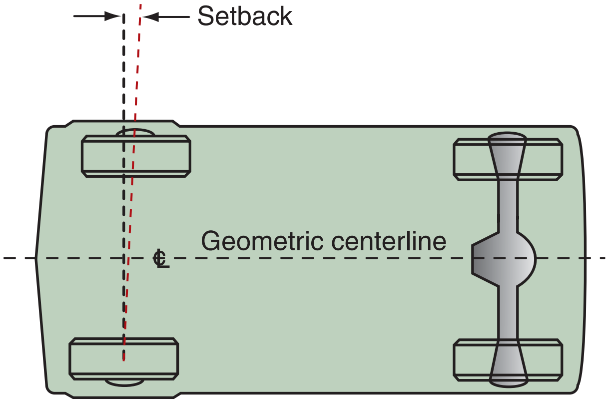


FIGURE 15-30 **Front or rear wheel setback.**

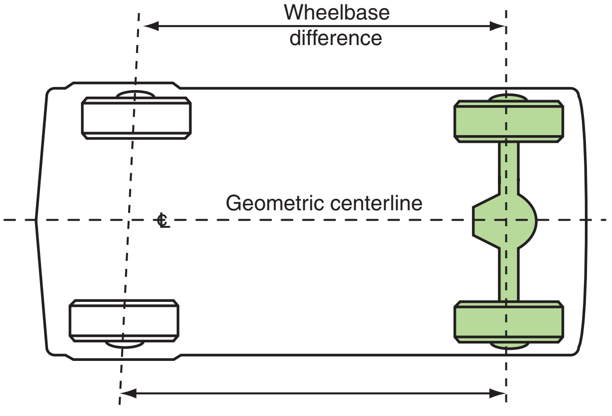


FIGURE 15-31 **Wheelbase difference.**

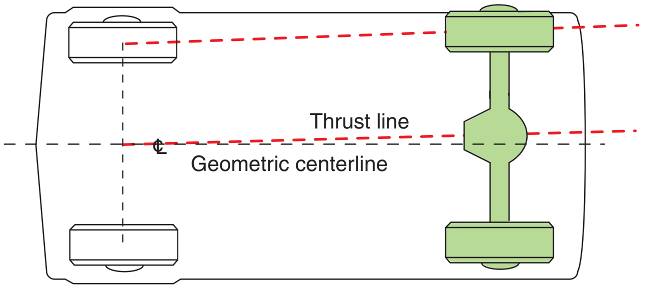


FIGURE 15-32 **Right or left lateral sideset.**

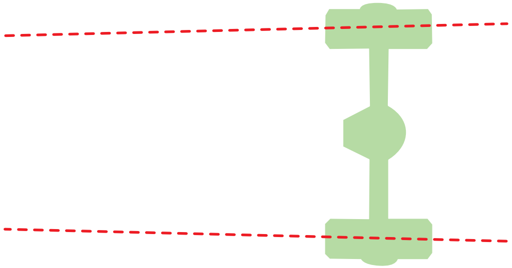


FIGURE 15-33 **Track-width difference.**

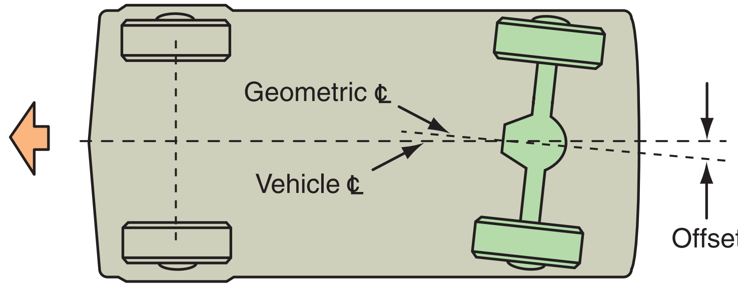


FIGURE 15-34 **Axle offset.**

connecting the centers of the right rear and right front wheels and the line connecting the centers of the left rear and left front wheels (Figure 15-33). Axle offset is an angle formed by the line that is projected forward at 90° in relation to the center of the rear axle and the thrust line (Figure 15-34).

Diagnostic Drawing and Text Screens

The technician may select tools and kits for the vehicle being serviced from the tools and kits database. When this feature is selected, the monitor screen displays the necessary wheel alignment adjustment tools for the vehicle selected at the beginning of the alignment (Figure 15-35). The kits displayed on the monitor screen are special components such as adjustment shims that are available for alignment adjustments on the car being serviced.

The technician may select **digital adjustment photos** that indicate how to perform wheel alignment adjustments (Figure 15-36). These digital photos include photos for cradle inspection and correction of cradle-to-body alignment (Figure 15-37). Live-action videos can also be selected. These CD videos provide suspension component inspection procedures (Figure 15-38).

A **part-finder database** is available in some computer wheel aligners. This database allows the technician to access part numbers and prices from many under-car parts manufacturers.

On many front-wheel-drive cars, the rear wheel camber and toe are adjusted with shims. Some computer aligners have a **shim display screen** that indicates the thickness of shim required and the proper position of the shim. On some computer wheel aligners, the technician may use the light pen to change the orientation angle of the shim on the monitor screen while observing the resulting change in camber and toe (Figure 15-39). Some computer wheel

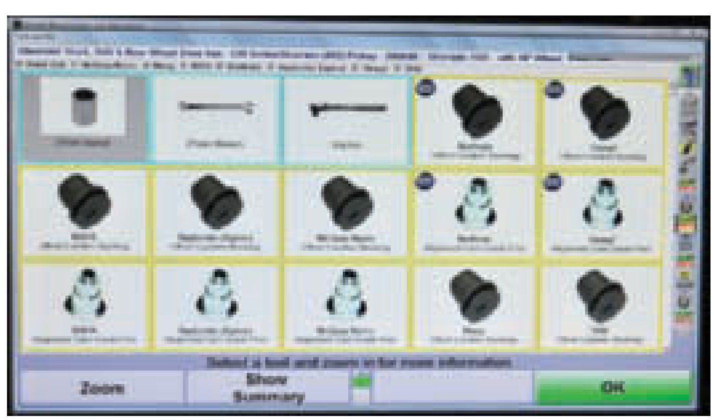


FIGURE 15-35 **Wheel alignment tools and kits display.**

FIGURE 15-36 **Wheel alignment adjustment photos.**

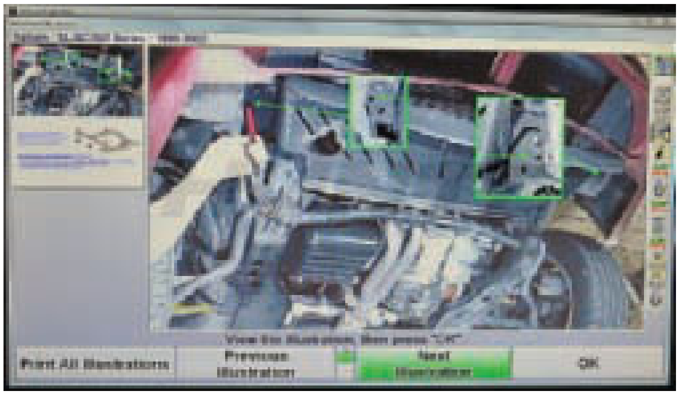


FIGURE 15-37 **Cradle inspection and correction photos.**

FIGURE 15-38 **Live-action videos of suspension inspection and service.**

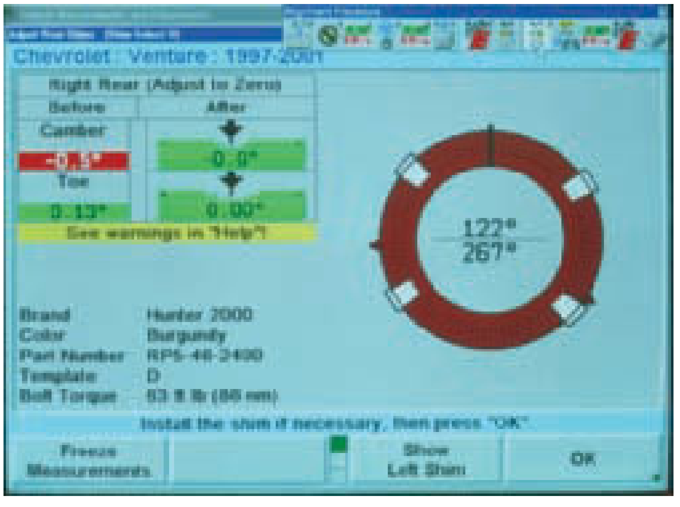


FIGURE 15-39 **Shim selection screen.**

FIGURE 15-40 **Automatic bushing calculation screen.**

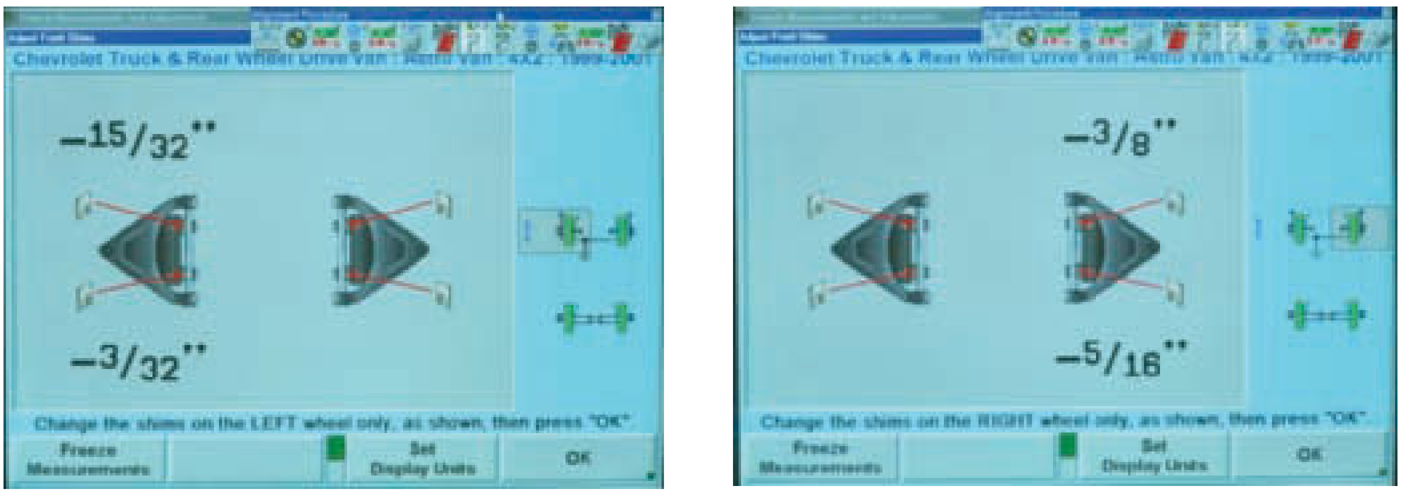


FIGURE 15-41 **Control arm movement monitor indicates the required shim thickness to provide specified camber and caster.**

aligners provide an automatic bushing calculator screen (Figure 15-40). This screen shows the required bushing and the proper bushing position to obtain the specified camber and caster on twin I-beam front suspension systems.

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A **control arm movement monitor** is available on some computer wheel aligners. On short-and-long arm front suspensions, this feature indicates the required shim thickness to provide the specified camber and caster (Figure 15-41).

On some computer wheel aligners, the technician may select Print at any time, and print out the displayed screen, including diagnostic drawings. Another optional procedure is to print out the wheel alignment report before and after the adjustment of wheel alignment angles.

Checking Toe Change and Steering Linkage Height

If the steering linkage on each side is not the same height, a condition called bump steer may occur. When bump steer occurs, the steering suddenly swerves to one side when one of the front wheels strikes a road irregularity. When this steering linkage condition is present, abnormal toe changes occur during wheel jounce and rebound.

Follow this procedure to check for abnormal toe changes during wheel jounce and rebound:

1. Be sure the toe is adjusted to specifications with the front wheels centered and the steering wheel locked.
2. Pull the chassis downward approximately 3 in. (7.6 cm) and observe the toe change.It is acceptable if the toe setting on each front wheel remains at the original reading or if each front wheel toes in or toes out an equal small amount (Figure 15-42).
3. During wheel jounce, if one front wheel toes inward or outward while the opposite wheel remains at the original setting, the steering linkage height is not equal and must be corrected (Figure 15-43).
4. During wheel jounce, if one front wheel toes in and the opposite front wheel toes out, the steering linkage height is unequal and must be corrected (Figure 15-44).
5. Push the chassis upward 3 in. (7.6 cm) and inspect the toe change (Figure 15-45). If the steering linkage height is equal, the toe setting on each front wheel remains the same or moves the same amount to a toe-in or toe-out position.
6. If the toe on one front wheel remains at the original setting while the opposite front wheel toe changes to a toe-in or toe-out setting, the steering linkage height is unequal. When one front wheel moves to a toe-in position, and the opposite front wheel moves to a toe-out setting, unequal steering linkages are indicated.

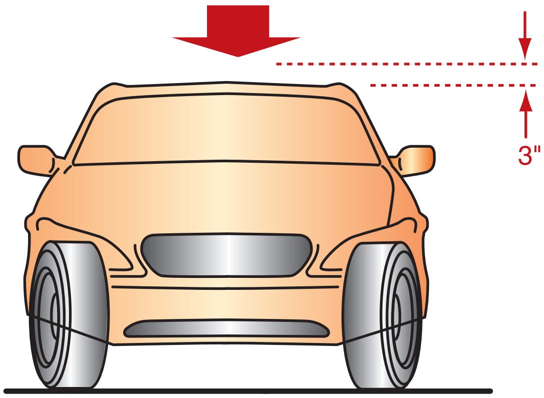

FIGURE 15-42 **Normal toe change during wheel jounce.**

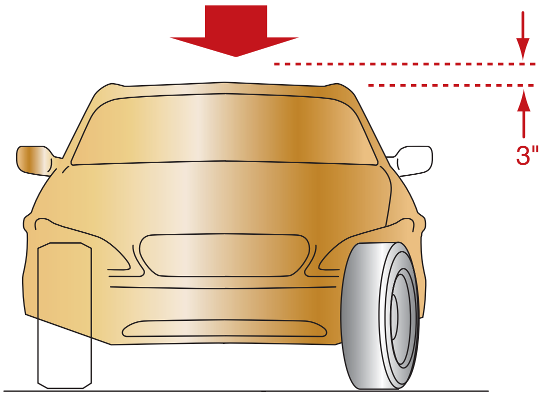

FIGURE 15-43 **If the toe change on one front wheel remains at the original setting while the toe on the opposite wheel toes in or out during wheel jounce, unequal steering linkage height is indicated.**

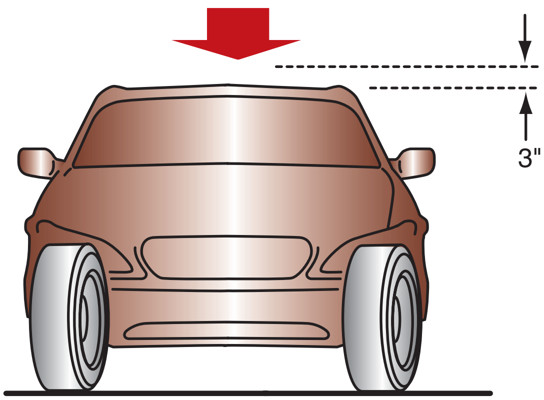

FIGURE 15-44 **If the toe on one front wheel toes in and the toe on the opposite front wheel toes out during wheel jounce, unequal steering linkage height is indicated.**

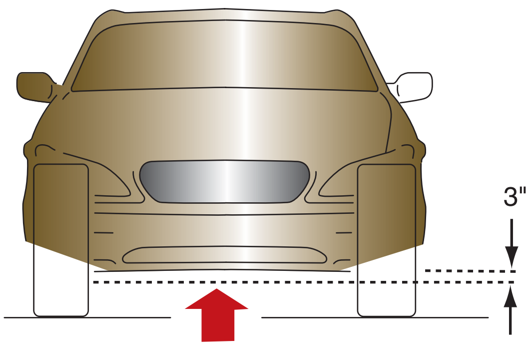

FIGURE 15-45 **Pull the chassis upward 3 in. (7.6 cm) to check for improper toe change indicating unequal steering linkage height.**

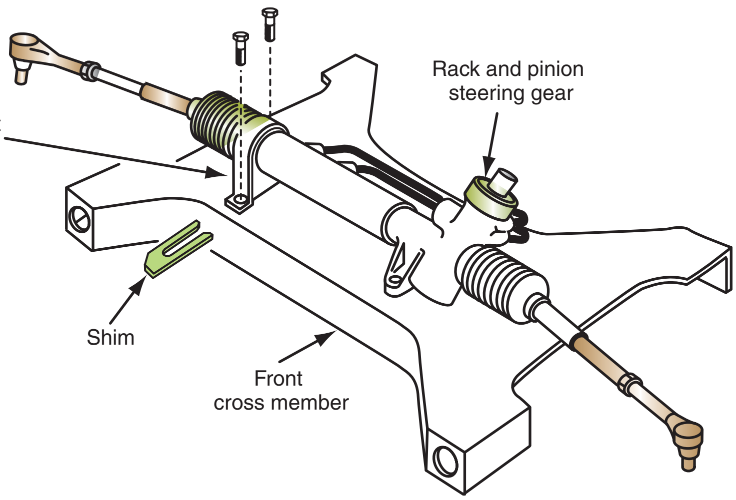

FIGURE 15-46 **On some imported vehicles, shims between the rack and pinion steering gear and the chassis adjust the steering linkage height.**

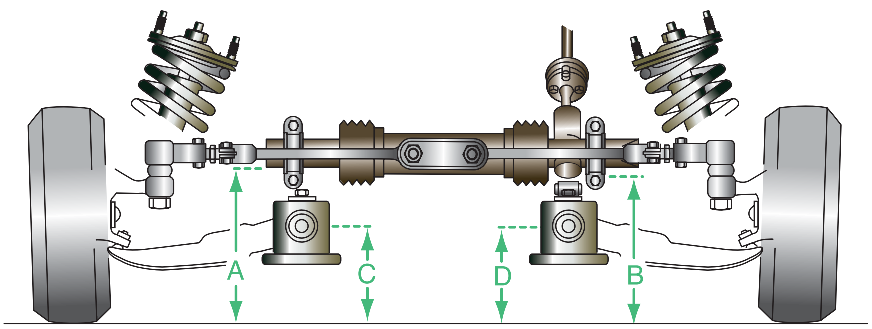

FIGURE 15-47 **Measuring rack and pinion steering gear height at various locations.**

On some imported vehicles, the steering linkage height can be adjusted with shims between the rack and pinion steering gear and the chassis (Figure 15-46). The idler arm may be moved upward or downward on some domestic vehicles to adjust the steering linkage height. On other vehicles, if the steering linkage height is unequal, steering components are worn or bent. These components include tie-rods, tie-rod ends, idler arms, pitman arms, and rack and pinion steering gear mounting bushings.

Another method of inspecting for equal tie-rod height on rack and pinion steering gears is to measure the distance from the center of the inner retaining bolt on the lower control arm to the alignment ramp on each side of the front suspension (distances A and B in Figure 15-47). If this distance is not equal on each side of the front suspension, one of the front springs may be sagged or such components as control arm bushings may be worn. When distances A and B are not equal, this problem must be corrected before performing the steering gear measurements. If distances A and B are equal, measure from the outer ends of the rack and pinion steering gear to the alignment ramp (distances C and D). If these distances are not equal, the rack and pinion steering gear mountings may be worn or distorted.

Bent Front Strut Diagnosis

Diagnostic Procedure

Front struts that are bent forward or rearward may be diagnosed as follows:

1. With the vehicle on the aligning rack and the magnetic gauges in position for the camber measurement, swing one front wheel out 10° and read the camber.

2. Turn the same wheel inward 10° and read the camber. The difference between the two readings is usually less than 4 1/2°. If the strut is bent forward or rearward, the difference in the camber readings will be excessive. A 10° difference is not uncommon.
3. Repeat steps 1 and 2 on the other front wheel.

Front struts could also be bent inward or outward. To diagnose this condition, use the following procedure:

1. With the wheel aligner in operation, sit on the front fender to load the suspension downward, and then read the camber.
2. Unload the suspension and lift up on the vehicle while the camber is recorded. The two camber readings should be within 1/2°. If the strut is bent inward or outward, the difference in the two camber readings will be excessive. A 4° to 6° camber change is not uncommon.
3. Repeat steps 1 and 2 on the other front wheel.

CUSTOMER CARE: Always concentrate on quality workmanship and customer satisfaction. Most customers do not mind paying for vehicle repairs if the work is done properly and their vehicle problem is corrected. To determine customer satisfaction, make follow-up phone calls a few days after repairing their vehicle. This indicates that you are interested in their vehicle and that you consider quality work and satisfied customers a priority.

CASE STUDY

A customer complained about erratic steering on a front-wheel-drive Dodge Intrepid. A road test revealed the car steered reasonably well on a smooth road surface, but while driving on irregular road surfaces, the steering would suddenly swerve to the right or left.

The technician performed a preliminary wheel alignment inspection and found the right tie-rod end was loose; all the other suspension and steering components were in satisfactory condition. The technician replaced the loose tie-rod end, but a second road test indicated that the bump steer problem was still present. After advising the customer that a complete wheel alignment was necessary, the technician drove the vehicle on the wheel aligner and carefully checked all front and rear alignment angles. Each front and rear wheel alignment angle was within specifications. The technician realized that somehow he had not diagnosed this problem correctly.

While thinking about this problem, the technician remembered a general diagnostic procedure he learned while studying automotive technology. This procedure stated: Listen to the customer complaints, be sure the complaint is identified, think of the possible causes, test to locate the exact problem, and be sure the complaint is eliminated. The technician realized he had not thought much about the causes of the problem, and so he began to recall the wheel alignment theory he learned in college. He remembered that the tie-rods must be parallel to the lower control arms, and if the tie-rod height is unequal, this parallel condition no longer exists. The technician also recalled that unequal tie-rod height causes improper toe changes during wheel jounce and rebound, which result in bump steer.

An inspection of the toe during front wheel jounce and rebound indicated the toe on the right front wheel remained the same during wheel jounce and rebound, but the toe on the left front wheel moved to a toe-out position. Since the tie-rods had been inspected during the preliminary alignment inspection, the technician turned his attention to the rack and pinion steering gear mounting. He found the bushing on the right end of the steering gear was worn and loose. This bushing was replaced and all the steering gear mounting bolts were tightened to the specified torque. An inspection of the toe change during wheel jounce and rebound revealed a normal toe change.

TERMS TO KNOW

Advanced vehicle handling (AVH)
Alignment ramp
Axle offset
Brake pedal depressor
Bump steer
Camber
Caster
Caster offset
Caster trail
Control arm movement monitor
Digital adjustment photos
Digital signal processor (DSP)
Front and rear wheel alignment angle screen
High-frequency transmitter
Included angle
Lateral axle sideset
Main menu
Memory steer
Part-finder database
Prealignment inspection
Preliminary inspection screen
Receiver
Ride height
Ride height screen
Rim clamps
Road test
Setback
Shim display screen
Slip plates
Specifications menu
Steering axis inclination (SAI)
Symmetry angle measurements
Thrust line
Tire inspection screen

Terms to Know (continued)

Toe-in

Toe-out

Torque steer

Total toe

Turntable

From this experience the technician learned the following two things:

1. His understanding of wheel alignment theory was very important in diagnosing steering problems.
2. Always be thorough! During a prealignment inspection, check all suspension and steering components, including rack and pinion steering gear mountings.

ASE-Style Review Questions

1. While discussing a front suspension height that is 1 in. (2.54 cm) less than specified:

   Technician A says the suspension height must be correct before a wheel alignment is performed.

   Technician B says the lower front suspension height may be caused by worn lower control arm bushings.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While performing a prealignment inspection:

   Technician A says improper front wheel bearing adjustment may affect wheel alignment angles.

   Technician B says worn ball joints have no effect on wheel alignment angles.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. While discussing a front suspension system in which the right front wheel has 2° positive camber and the left front wheel has 1/2° positive camber:

   Technician A says when the vehicle is driven straight ahead, the steering will pull to the left.

   Technician B says there will be excessive wear on the inside edge of the left front tire tread.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. When discussing unsatisfactory steering wheel returnability:

   Technician A says the rack and pinion steering gear mounts may be worn.

   Technician B says this problem may be caused by interference between the dash seal and the steering shaft.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

5. While discussing turning radius measurement:

   Technician A says a bent steering arm will cause the turning radius to be out-of-specification.

   Technician B says if the turning radius is not within specification, tire tread wear is excessive while cornering.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

6. While measuring and adjusting front wheel toe:

   A. If the positive caster is increased on the right front wheel, this wheel moves toward a toe-in position.
   B. Improper front wheel toe setting causes steering wander and drift.
   C. The front wheel toe should be checked with the front wheels straight ahead.
   D. Improper front wheel toe setting causes wear on the inside edge of the tire tread.

7. All of these statements about front wheel toe change during wheel jounce and rebound are true EXCEPT:

   A. If one front wheel toes in and the opposite front wheel toes out during front wheel jounce and rebound, the tie-rod height is unequal.
   B. If both front wheels toe in or toe out a small, equal amount during front wheel jounce and rebound, the tie-rods are parallel to the lower control arms.
   C. The improper toe change during front wheel jounce and rebound may cause bump steer.
   D. Improper toe change during front wheel jounce and rebound may be caused by a worn upper strut mount.

8. While using a computer wheel aligner:
   - A. The technician may select defective suspension components from a list on the screen.
   - B. It is not necessary to check or compensate for wheel runout.
   - C. If the camber bar graph is red, the camber setting is within specifications.
   - D. A wheel sensor containing a high-frequency transmitter requires a cable connected to the aligner computer.

9. While using computer wheel aligners:
   - A. On many computer wheel aligners, the technician may only print out the four-wheel alignment results.
   - B. Some wheel sensors have the capability to measure ride height and display this reading on the screen.
   - C. A front wheel swing is necessary before reading the front wheel camber.
   - D. If the computer aligner contains a control arm movement monitor, the technician has to estimate the necessary shim thickness.

10. While using computer wheel aligners:
   - A. Symmetry angle measurements display thrust angle, rear wheel toe, and rear wheel camber.
   - B. Setback is the angle formed by a line at 90° to the vehicle centerline at the axle attachment point and a line through the left and right wheel centers.
   - C. Wheelbase difference is an angle created by a line through the rear wheel centers and the thrust line.
   - D. Right or left lateral offset is an angle between a line through the left front and left rear tires and a line between the right front and right rear tires.

ASE Challenge Questions

1. While discussing turning radius:

   Technician A says incorrect turning radius may often be noted by tire squeal while cornering.

   Technician B says to adjust turning radius toe-out on turns, turn the inner wheel to stop.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. The customer says that sometimes her car suddenly swerves to one side on a bump. All of the following could cause this problem EXCEPT:
   - A. Loose steering gear.
   - B. Worn tie-rods.
   - C. Sagging front springs.
   - D. Steering gear lash adjustment.

3. While discussing steering diagnosis:

   Technician A says uneven half-shaft axle lengths may cause a vehicle to pull to one side when accelerating.

   Technician B says abnormal toe changes can cause a vehicle to pull to one side on road irregularities.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. After you have completed a front end alignment, a customer returns to your shop and complains of continued vehicle drift. To correct this problem, you should:
   - A. Inspect the manual steering gear for possible mis-centering of the sector gear.
   - B. Inspect rear wheel alignment.
   - C. Ask the customer to fill the fuel tank.
   - D. Inspect the steering column flex coupling.

5. While performing a prealignment inspection:

   Technician A says a prealignment inspection should include checking the vehicle interior for heavy items.

   Technician B says tools and other items normally carried in the vehicle should be included during an alignment.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

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Name ______________________________ Date ____________________

Road-Test Vehicle and Diagnose Steering Operation

Upon completion of this job sheet, you should be able to road-test a vehicle and diagnose steering operation.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task E-1: Diagnose vehicle wander, drift, pull, hard steering, bump steer, memory steer, torque steer, and steering return concerns; determine necessary action.

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ____________________

VIN ______________________________ Engine type and size ____________________

Procedure

Task Completed

1. Road-test vehicle under such driving conditions as slow-speed driving, cornering, and normal cruising speed while driving on a straight, level road surface. Check for the following abnormal steering conditions:
2. Vertical chassis oscillations: ☐ Satisfactory ☐ Unsatisfactory
3. Chassis lateral waddle: ☐ Satisfactory ☐ Unsatisfactory
4. Steering pull to right: ☐ Satisfactory ☐ Unsatisfactory
5. Steering pull to left: ☐ Satisfactory ☐ Unsatisfactory
6. Steering effort: ☐ Satisfactory ☐ Unsatisfactory
7. Tire squeal while cornering: ☐ Satisfactory ☐ Unsatisfactory
8. Bump steer: ☐ Satisfactory ☐ Unsatisfactory
9. Torque steer: ☐ Satisfactory ☐ Unsatisfactory
10. Memory steer: ☐ Satisfactory ☐ Unsatisfactory
11. Steering wheel return: ☐ Satisfactory ☐ Unsatisfactory
12. Steering wheel free play: ☐ Satisfactory ☐ Unsatisfactory
13. Return the vehicle to the shop and inspect suspension and steering to determine the cause of abnormal conditions. List the necessary repairs and/or adjustments to correct all abnormal conditions that occurred during the road test.

    ____

    ____

Instructor's Response ____

____

____

Name ______________________________ Date ____________________

Measure Front and Rear Wheel Alignment Angles with a Computer Wheel Aligner

Upon completion of this job sheet, you should be able to measure front and rear wheel alignment with a computer wheel aligner.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Tasks:

E-2. Perform prealignment inspection and measure vehicle ride height; perform necessary action.
E-3. Prepare vehicle for wheel alignment on the alignment machine; perform four-wheel alignment by checking and adjusting front and rear wheel caster, camber, and toe as required; center steering wheel.
E-4. Check toe-out on turns (turning radius); determine necessary action.
E-5. Check steering axis inclination (SAI) and included angle; determine necessary action.
E-6. Check rear wheel thrust angle; determine necessary action.
E-7. Check front wheel setback; determine necessary action.
E-8. Check front and/or rear cradle (subframe) alignment; determine necessary action.

Tools and Materials

Computer wheel aligner

Describe the Vehicle Being Worked On:

Year __________ Make ________________ Model ____________________________

VIN ______________________________ Engine type and size ______________________

Procedure

Task Completed

WARNING: When you drive a vehicle onto an alignment ramp, be sure no one is standing in front of the vehicle to avoid causing personal injury.

1. Lock the front turntables and drive the vehicle onto the alignment ramp. Apply the parking brake.

   Are the front tires properly positioned on the front turntables? ☐ Yes ☐ No

   Are the rear tires properly positioned on the slip plates? ☐ Yes ☐ No

   Instructor check ____

Task Completed

2. Install the rim clamps and wheel sensors. Perform wheel sensor leveling and wheel runout compensation procedures.

   Are the wheel sensors level? ☐ Yes ☐ No

   Is the wheel runout compensation procedure completed? ☐ Yes ☐ No

   Instructor check ______________________________

3. Select the specifications for the vehicle being aligned.

   Are the specifications selected? ☐ Yes ☐ No

   Instructor check ______________________________

4. Perform a prealignment inspection using the checklist in the computer wheel aligner. List any components that must be repaired or replaced, and explain the reasons for your diagnosis.

   ____
   ____
   ____
   ____
   ____

5. Measure the ride height.

   Left front ride height ________ Specified ride height ________

   Right front ride height ________ Specified ride height ________

   Left rear ride height ________ Specified ride height ________

   Right rear ride height ________ Specified ride height ________

   State the necessary repairs to correct ride height and explain the reasons for your diagnosis.

   ____
   ____
   ____
   ____

6. Measure the front and rear suspension alignment angles following the prompts on the computer wheel aligner screen.

   Left front camber ________ Right front camber ________

   Cross camber ________ Specified front wheel camber ________

   Specified cross camber ________

   Left front caster ________ Right front caster ________

   Cross caster ________ Specified front wheel caster ________

   Specified cross caster ________

   Left front SAI ________ Right front SAI ________

   Specified SAI ________ Included angle ________

Thrust angle ____________

Task Completed

Specified thrust angle ____________

Left front toe ____________ Right front toe ____________

Total toe ____________ Specified front wheel toe ____________

Left rear camber ____________ Right rear camber ____________

Specified camber ____________

Left rear toe ____________ Right rear toe ____________

Total toe ____________ Specified rear wheel toe ____________

State the necessary adjustments and repairs to correct front and rear suspension alignment angles and explain the reasons for your diagnosis.

____

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____

____

7. Measure the turning radius.

Left turn: Turning radius right front wheel ____________

Turning radius left front wheel ____________

Specified turning radius ____________

Right turn: Turning radius left front wheel

Turning radius right front wheel ____________

Specified turning radius ____________

State the necessary repairs to correct the turning radius, and explain the reasons for your diagnosis.

____

____

____

____

____

____

Instructor's Response ____

____

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Name ______________________ Date ______________

Check Proper Steering Linkage Heightby Measuring Toe Change

Upon completion of this job sheet, you should be able to check steering linkage height by measuring toe change.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task A-2: Identify and interpret suspension and steering system concerns; determine necessary action.

Tools and Materials

Computer wheel aligner

Describe the Vehicle Being Worked On:

Year __________ Make ______________ Model ______________________

VIN ______________________ Engine type and size ______________________

Procedure

Task Completed

1. Be sure the toe is adjusted to specifications with the front wheels centered and the steering wheel locked.

   Toe, left front __________

   Toe, right front __________

   Total toe, front wheels __________

2. Pull the chassis downward approximately 3 in. (7.6 cm) and record the toe change.

   Toe change left front from __________ to __________

   Toe change right front from __________ to __________

3. During the wheel jounce in step 2, did the toe remain at the original setting on the left front? Amount of toe change from the original setting on the left front wheel

   ____

   During the wheel jounce in step 2, did the toe remain at the original setting on the right front? Amount of toe change from the original setting on the right front wheel

   ____

4. During the wheel jounce in step 2, did the right and the left front wheels move an equal amount toward a toe-in position? Amount of toe change toward a toe-in position on both front wheels __________

5. During the wheel jounce in step 2, did one front wheel move toward a toe-in or toe-out position while the opposite front wheel remained at the original position? Amount that one front wheel moved toward a toe-in or toe-out position while the opposite front wheel remained at the original position __________

Task Completed ______

6. During the wheel jounce in step 2, did one front wheel move toward a toe-in and the opposite front wheel move toward a toe-out position?

   Amount that one front wheel moved toward a toe-in position ______

   Amount the opposite front wheel moved toward a toe-out position ______

7. Push the chassis upward 3 in. (7.6 cm) and inspect the toe change.

   Left front toe change: from ______ to ______

   Right front toe change: from ______ to ______

8. During the wheel rebound in step 7, did one front wheel remain at the original setting and the opposite front wheel move toward a toe-in or toe-out position?

   Amount that one front wheel moved toward a toe-in or toe-out position while the opposite front wheel remained at the original setting ______

9. During the wheel rebound in step 7, did one front wheel move toward a toe-in position while the opposite front wheel moved toward a toe-out position?

   Amount that one front wheel moved toward a toe-in position, and the amount the opposite front wheel moved toward a toe-out position ______

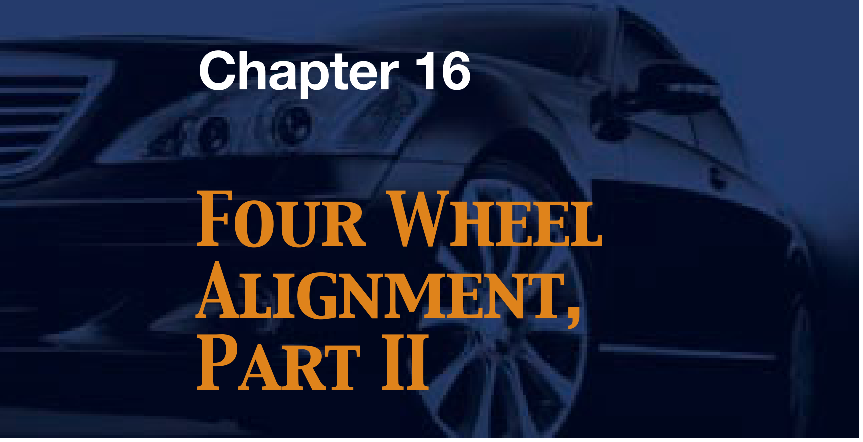
10. List all the abnormal conditions that indicate unequal steering arm height.

    ______
    ______
    ______
    ______

11. Inspect the front steering linkages and steering gear mountings, and list the necessary repairs to correct the improper toe change during wheel jounce and rebound. Explain the reasons for your diagnosis.

    ______
    ______
    ______

Instructor's Response ______
______
______



Chapter 16

Four Wheel Alignment, Part II

Upon completion and review of this chapter, you should be able to understand and describe:

- The steering axis inclination (SAI) angle and the included angle.
- How SAI helps return the front wheels to the straight-ahead position.
- How SAI eliminates the need for excessive positive camber and caster.
- The effect that front suspension defects such as dislocated upper strut towers and bent struts or spindles have on SAI.
- Negative and positive scrub radius and the effect of each on steering quality.
- Setback on front suspension systems.
- Toe-in and toe-out on front suspension systems.
- The toe-in settings required on front-wheel-drive and rear-wheel-drive vehicles.
- Tire tread wear caused by excessive toe-in.
- How the front suspension system is designed to provide toe-out on turns.
- The customer complaints that may arise from incorrect rear wheel toe and thrust line adjustments.
- Suspension and chassis defects that may cause improper rear wheel toe, thrust line, or camber.

Introduction

Improper steering axis inclination (SAI) angles on either side of the front suspension may cause hazardous steering conditions while braking or accelerating. Therefore, technicians must be familiar with SAI and other related steering geometry.

When the front wheel toe is not adjusted to the manufacturer's specifications, front tire tread wear is excessive. If one of the tie-rods is not parallel to the lower control arms, toe change on the front wheels is not equal during front wheel jounce and rebound. This action may result in bump steer when a front wheel strikes a road irregularity. While checking front wheel toe, improper toe change during suspension jounce and rebound should be checked to be sure the tie-rods are parallel to the lower control arms. Technicians must understand front wheel toe and improper toe changes.

Technicians must be familiar with the symptoms that indicate incorrect rear wheel alignment. The rear wheel alignment procedures required to correct improper rear wheel alignment must be understood.

Steering Axis Inclination (SAI) Definition

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On front-wheel-drive vehicles with MacPherson strut front suspension systems, **steering axis inclination (SAI)** refers to the inward tilt of a line through the center of the top strut mount and the center of the lower ball joint in relation to the true vertical line through the center of the tire. These two lines are viewed from the front of the vehicle, and the SAI line always tilts inward in relation to the true vertical line (Figure 16-1).

Many rear-wheel-drive cars have a short-and-long arm front suspension system with unequal-length upper and lower control arms and a ball joint mounted in each control arm. The steering knuckle and spindle pivot on the ball joints as the wheels are turned. On this type of front suspension, the SAI line runs through the upper and lower ball joint centers. The **included angle** is the sum of the SAI angle and the camber angle (Figure 16-2).

If the camber angle is positive, this angle is added to the SAI angle to obtain the included angle. A negative camber angle must be subtracted from the SAI angle to calculate the included angle. On some truck front suspension systems, the steering knuckle pivots on a king pin that is mounted in an I beam-type front axle. The SAI line on this type of suspension is referred to as a **king pin inclination (KPI)** line. This invisible line runs through the center of the king pin.

AUTHOR'S NOTE: It has been my experience that after front-end collision damage, a common problem for cars with a unitized body is improperly positioned strut towers. Even though the cosmetic appearance of the car body remains good, the strut towers may be out-of-position, resulting in unequal steering axis inclination (SAI) between the right and left front wheels. During severe braking, an unequal SAI causes steering pull and possible loss of steering control. Therefore, after a frontal collision on a unitized-body car, it is very important that you measure the strut tower location, and be sure this measurement is within specifications. It is also critical that you check the front and rear end wheel alignment and adjust the alignment angles as necessary to bring them within specifications.

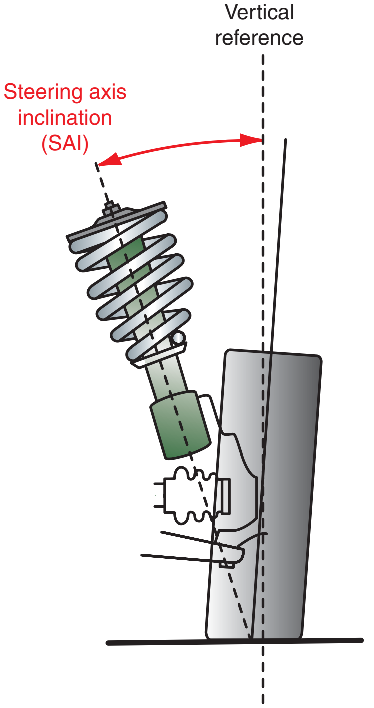

FIGURE 16-1 **Steering axis inclination angle.**

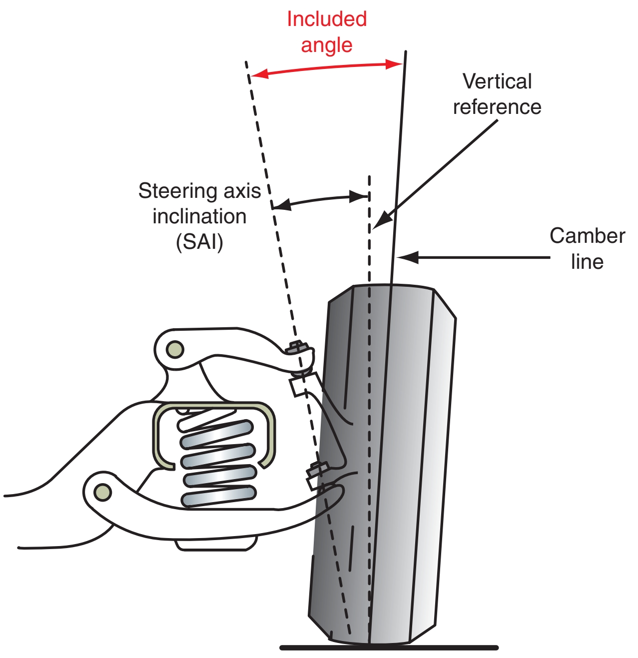

FIGURE 16-2 **Steering axis inclination and included angle.**

SAI Purpose

When the SAI angle is tilted toward the center of the vehicle and the wheels are straight ahead, the height of the spindle is raised closer to the chassis. This action lowers the height of the vehicle because of gravity. When the front wheels are turned, each spindle moves through an arc that tries to force the tire into the ground. Since this reaction cannot take place, the chassis lifts when the wheels are turned. When the steering wheel is released after a turn, the vehicle weight has a tendency to settle to its lowest point. Therefore, SAI helps return the wheels to the straight-ahead position after a turn, and it also tends to maintain the wheels in the straight-ahead position. However, SAI does increase steering effort because the chassis has to lift slightly on turns.

The vehicle weight is projected through the SAI line to the road surface. Let us assume that a front suspension is designed with a vertical 0° SAI line. Under this condition, the vehicle weight is projected through the SAI line a considerable distance inside the true vertical tire centerline. With this type of front suspension, severe tire scuffing would occur because the tire and wheel pivot around the SAI line during a turn (Figure 16-3).

With a 0° SAI line, greater steering effort is required during a turn and stress on the steering mechanism increases. This type of front suspension design causes excessive road shock and kick-back on the steering wheel during a turn, because the distance between the SAI line and the tire vertical line returns the wheels to the straight-ahead position.

When the SAI line meets the tire vertical centerline at the road surface, tire wear is reduced, steering effort is decreased, and stress on steering components is diminished (Figure 16-4).

The point at which the SAI line and the tire vertical centerline intersect could be positioned closer together by designing the front suspension with excessive positive camber. However, this design would result in rapid wear on the outside edge of the tire tread. A correct SAI line reduces the need for excessive positive camber.

MacPherson strut front suspension systems have a much greater SAI angle (12° to 18°) compared with short-and-long arm front suspensions in rear-wheel-drive cars (6° to 8°). Front-wheel-drive cars require the higher SAI angle for directional stability. Positive caster also provides directional stability. Since SAI helps maintain the front wheels in the straight-ahead position, SAI reduces the need for excessive positive caster.

SAI and Safety Factors

On MacPherson strut suspension systems, an incorrect SAI angle may indicate that the upper strut mount is out of position, the lower control arm is bent, or the center cross member is shifted. Any of these defects may be caused by collision damage.

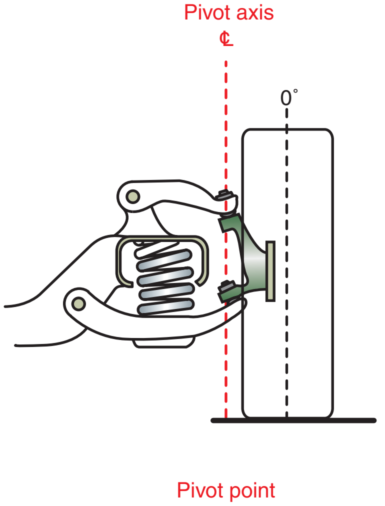

FIGURE 16-3 **Front suspension with a 0° SAI line.**

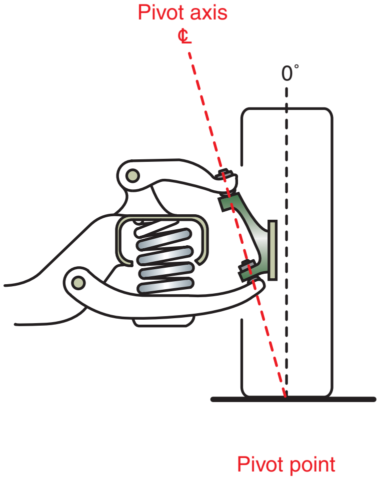

FIGURE 16-4 **If the SAI line meets the tire vertical centerline at the road surface, tire wear is reduced, steering effort is decreased, and stress on the steering components is diminished.**

When the SAI angles are unequal on the left and right front suspension, serious handling problems may occur. These problems include torque steering during hard acceleration, steering pull during sudden stops, and bump steer. Torque steer is the tendency to pull to one side on hard acceleration because of unequal-length drive axles on a front-wheel-drive vehicle. Unequal SAI angles aggravate torque steer. Bump steer refers to unequal toe and/or camber changes that jerk the car to one side during front suspension jounce and rebound. Therefore, incorrect SAI angles may cause hazardous driving situations and contribute to serious accidents. Technicians must inspect the SAI angle during a wheel alignment.

If the SAI angle is correct and the included angle and camber are less than specified, bent components such as the strut or spindle are indicated. On the type of suspension that requires inward or outward upper strut movement to adjust camber, the SAI angle changes with this movement. When an eccentric bolt between the strut and steering knuckle is used for camber adjustment, the SAI angle will not change if the camber is adjusted.

It is very important to remember that a camber adjustment on many front suspension systems also changes the SAI angle. For example, if the upper control arm on a front suspension system with upper and lower ball joints is shimmed outward to increase positive camber, the SAI angle will change with the camber angle. Therefore, the included angle remains the same. The camber may be adjusted to specification, but the SAI angle and included angle could be out of specification. This is especially true on MacPherson strut suspension systems where collision damage may bend front struts or shift the upper strut towers. A service technician who inspects and adjusts the camber angle while ignoring the SAI and included angles may be overlooking serious and dangerous front suspension defects.

Scrub Radius

Scrub radius is the distance between the SAI line and the true vertical centerline of the tire at the road surface.

Scrub radius affects steering quality related to stability and returnability. However, scrub radius is not an alignment angle and it cannot be measured on conventional alignment equipment. Scrub radius is the distance from the point where the tire vertical line contacts the road to the location where the line through the upper strut center and the ball joint center meets the road surface. **Positive scrub radius** occurs when the line through the strut and ball joint meets the road surface inside the tire vertical centerline. A **negative scrub radius** is when the line through the strut and ball joint centers meets the road surface outside the tire and hub centerline (Figure 16-5).

Conventional short-and-long arm front suspension systems usually have positive scrub radius. Many front-wheel-drive vehicles have negative scrub radius.

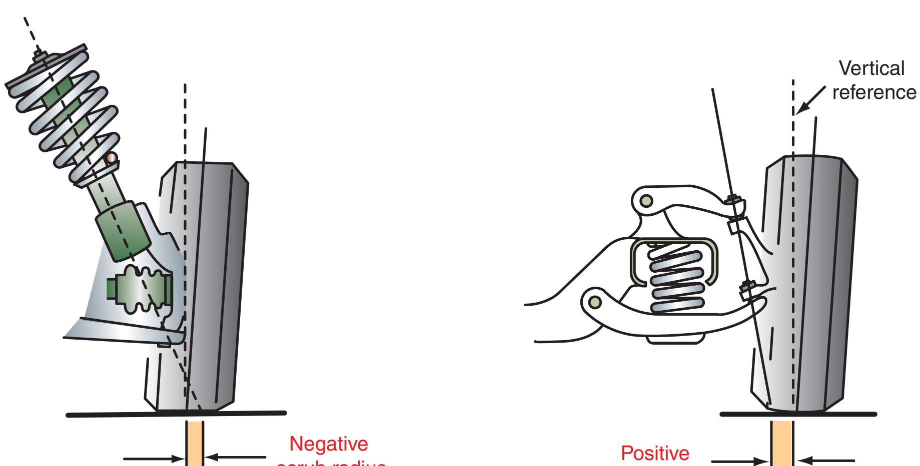

FIGURE 16-5 **Scrub radius.**

When negative scrub radius is used in front-wheel-drive vehicles, straight-line braking is ensured and directional stability is maintained. As the vehicle moves forward, negative scrub radius tends to turn the front wheels inward. This action causes unequal forces applied to the steering to act inboard of the steering axis and pull the vehicle from any induced swerve. In a front-wheel-drive vehicle, a swerve to one side may be caused by one front wheel being on an ice patch while the other front wheel is on dry pavement. A failure of one-half the diagonal brake system, a sudden blowout of one front tire, or a grabbing brake on one front wheel will also cause a vehicle to swerve.

If a vehicle has positive scrub radius and the right front brake grabs, both the positive scrub radius and the grabbing brake tend to turn the right front wheel outward, and the vehicle pivots around the right front wheel. This action induces a swerve to the right.

When a right front brake grab occurs with negative scrub radius, the brake grab causes the right front wheel to turn outward, and the vehicle tends to pivot around the right front wheel. However, the negative scrub radius tends to turn the right front wheel inward. The two forces on the right front wheel cancel each other to maintain directional stability.

Scrub Radius and Safety

If front tires that are larger in diameter than specified by the car manufacturer are installed, directional control may be affected. Large tires raise the chassis farther from the road surface, which changes the scrub radius. The installation of larger front tires could change a positive scrub radius to a negative scrub radius.

Reversing the front rims so they are inside out creates a significant scrub radius change and adversely affects directional control. This practice is not recommended by car manufacturers.

WARNING: Installing larger tires, or different rims than the ones specified by the vehicle manufacturer, changes the scrub radius, which may result in reduced directional control, collision damage, and personal injury.

Wheel Setback

Wheel setback is a condition in which one wheel is moved rearward in relation to the other wheel (Figure 16-6). Setback will not affect handling unless it is extreme. Collision damage may drive one front strut rearward and cause extreme setback. Setback can also occur on rear wheels, but it is more likely to occur on front wheels because of collision damage. Some computer four wheel aligners have setback measuring capabilities.

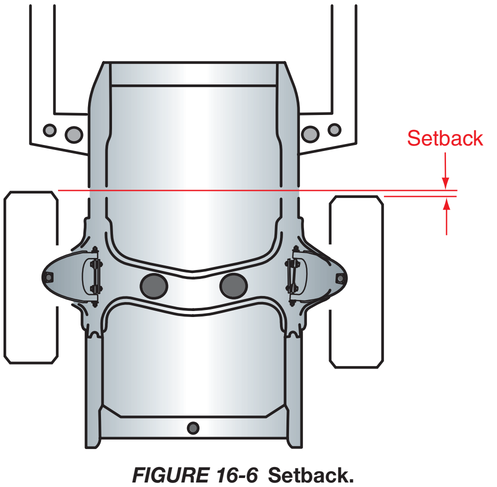

FIGURE 16-6 **Setback.**

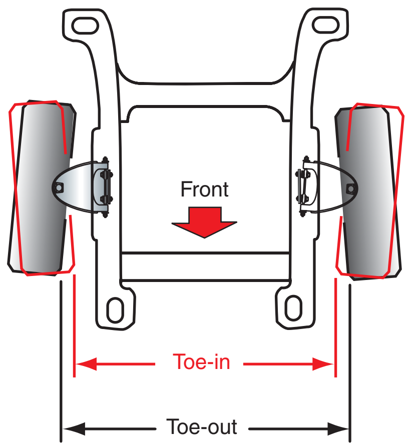

FIGURE 16-7 **Toe-in and toe-out.**

Toe Definition

When the distance between the rear inside tire edges is greater than the distance between the front inside tire edges, the front wheels have a **toe-in** setting. **Toe-out** occurs when the distance between the inside front tire edges exceeds the distance between the inside rear tire edges (Figure 16-7).

Toe Setting for Front-Wheel-Drive and Rear-Wheel-Drive Vehicles

On a front-wheel-drive vehicle, the front drive axle torque forces the front wheels toward an increased toe-in position. Therefore, car manufacturers usually specify a slight toe-out position for the front wheels on these vehicles.

On rear-wheel-drive vehicles, front tire friction on the road surface moves the wheels toward the toe-out position when the car is driven. On this type of vehicle, manufacturers usually specify a slight toe-in on the front wheels. The front wheels are adjusted to a slight toe-in or toe-out with the vehicle at rest so the wheels will be parallel to each other when the vehicle is driven on the road. A slight amount of lateral movement always exists in steering linkages. Forces acting on the front wheels try to compress or stretch the steering linkages when the vehicle is driven. Whether a compressing or stretching action occurs on the steering linkage depends on whether the steering linkages are located at the rear edge or front edge of the front wheels.

Toe Adjustment and Tire Wear

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Ford Motor Company has calculated that a toe-in error of 1/8 in. (3.17 mm) is equivalent to dragging the tires crosswise for 11 ft. (3.3 m) for each mile the vehicle is driven. This crosswise movement causes severe feathered tire tread wear (Figure 16-8). Improper toe adjustment is the most common cause of rapid tire tread wear.

CAUTION: Improper toe adjustment causes rapid tire tread wear, which may result in tire failure.

Excessive toe-out causes wear on the inside of the tire tread ribs and a sharp feathered edge on the outside of the tread ribs. If excessive toe-in is present, the tire tread wear is reversed.

Worn steering linkage components such as tie-rod ends cause incorrect and erratic toe-in settings. If the front springs become weak, the front suspension height is lowered. When this occurs, the pitman arm and the idler arm move downward with the chassis. This action moves the tie-rods to a more horizontal position that tends to push outward on the steering arms and increases front wheel toe-in. The toe-in change just described occurs when the steering linkage is located at the rear of the front wheels.

WARNING: Worn steering components may suddenly become disconnected, causing complete loss of steering control, collision damage, and personal injury.

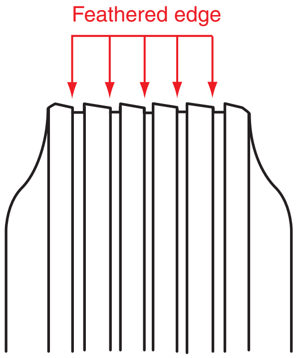

FIGURE 16-8 **Feathered tire tread wear caused by incorrect toe adjustment.**

Turning Radius

Front and Rear Wheel Turning Action

When a vehicle turns a corner, the front and rear wheels must turn around a common center with respect to the **turning radius** (Figure 16-9). On most front suspension systems, the front wheels pivot independently at different distances from the center of the turn, and therefore the front wheels must turn at different angles. The inside front wheel must turn at a sharper angle than the outside wheel. This is because the inside wheel is actually ahead of the outside wheel. When this turning action occurs, both front wheels remain perpendicular to their turning radius, which prevents tire scuffing.

The turning angles of the front wheels are determined by steering arm design, and these angles are not adjustable. If the steering angles are not correct, the steering arms may be bent.

Turning radius may be referred to as cornering angle or toe-out on turns.

Steering Arm Design

An understanding of a lever moving in a circle is necessary before an explanation of steering arm design and operation. If a lever moves from point A to B, it pivots around point O and moves through a horizontal distance A to B (Figure 16-10).

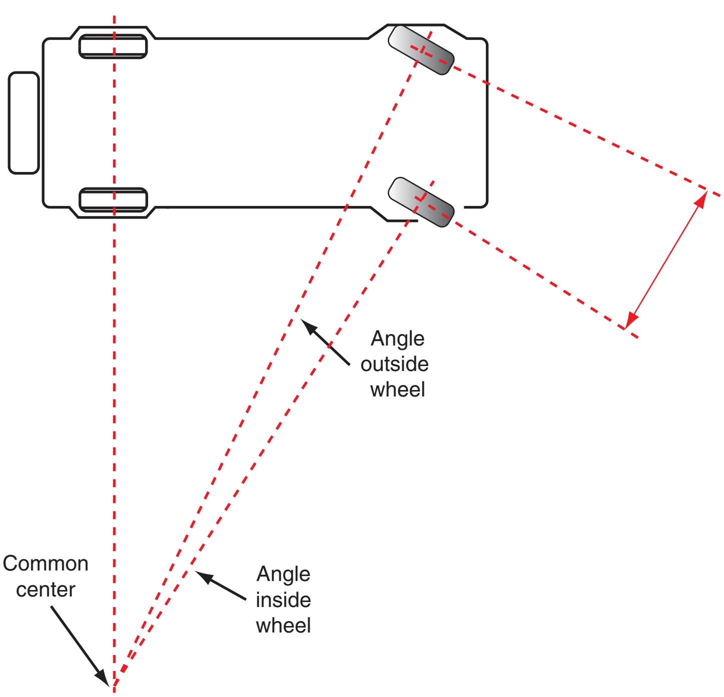

FIGURE 16-9 **Front and rear wheels turning around a common center.**

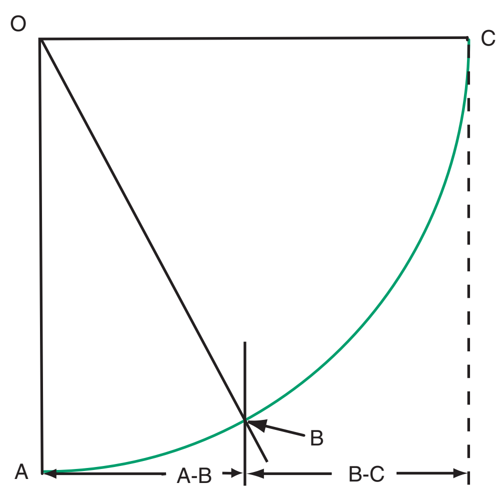

FIGURE 16-10 **Lever movement in a circle.**

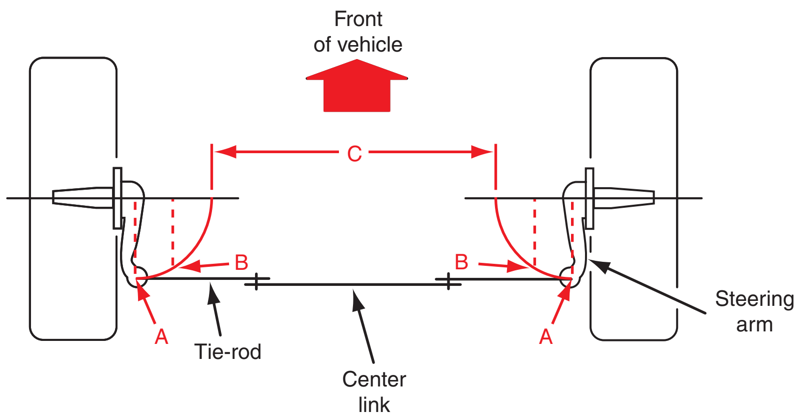

FIGURE 16-11 **Steering arms are closer together at the point where the tie-rods connect than at their spindle pivot points.**

Lever movement through arc B to C is much greater than the movement through arc A to B. However, during arc B to C, the lever moves through horizontal distance B to C and this distance is the same as horizontal distance A to B.

The steering arms are connected from the tie-rod ends to the steering knuckles. Steering arms and linkages maintain the front wheels parallel to each other when the vehicle is driven straight ahead. However, the steering arms are not parallel to each other. If the steering linkage is at the rear edge of the front wheels, the steering arms are closer together at the point where the tie-rods connect than at their spindle pivot point (Figure 16-11). When the steering linkage is positioned at the front edge of the front wheels, the steering arms are closer together at their spindle pivot point than at the tie-rod connecting point.

When the front wheels are turned on a vehicle with the steering linkage at the rear edge of the front wheels, the angle formed by the inside steering arm and linkage increases, whereas the angle of the outside steering arm and linkage decreases. The inside steering arm moves through the longer arc X, and the outside steering arm moves through shorter arc Z (Figure 16-12).

Toe-out on turns is the angle of the inside wheel in relation to the angle of the outside wheel during a turn.

Therefore, the inside wheel turns at a sharper angle than the outside wheel. Since both steering arms are designed to have the same angle in the straight-ahead position, the inside front wheel always has a sharper angle regardless of the turning direction. The sharper inside wheel angle during a turn causes the inside wheel to toe out. Therefore, the term **toe-out on turns** is used for this steering action. If the front wheel turning angle is increased during a turn, the amount of toe-out on the inside wheel increases proportionally.

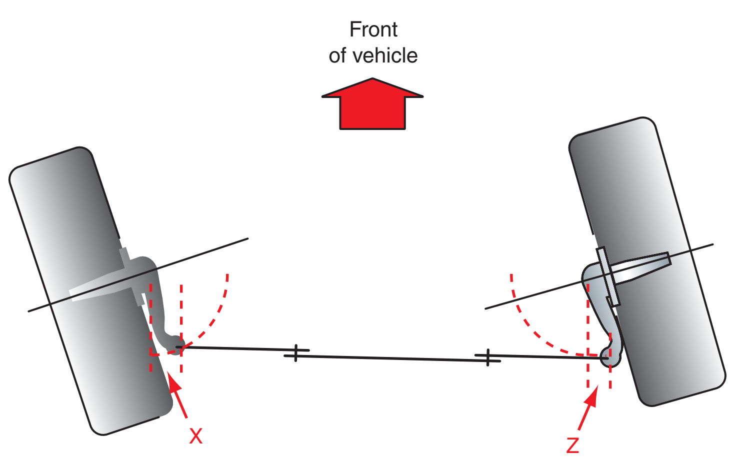

FIGURE 16-12 **Steering arm operation while turning.**

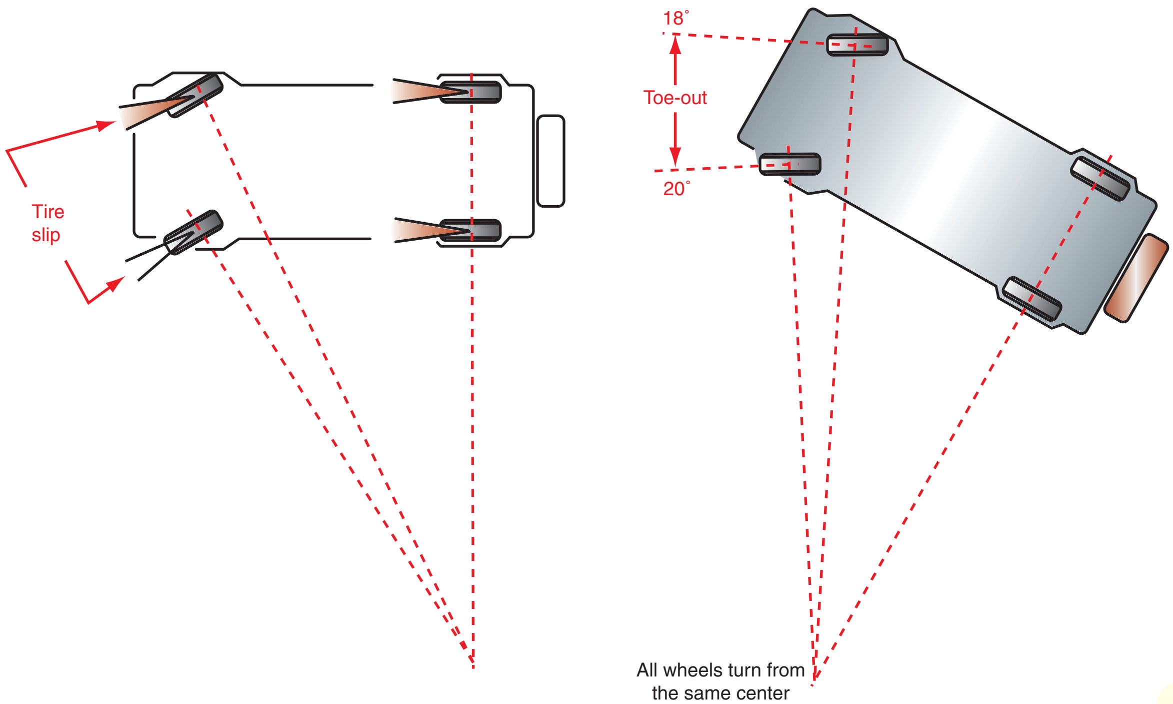

FIGURE 16-13 **Slip angle during a turn.**

Slip Angle

During a turn, centrifugal force causes all the tires to slip a certain amount. The amount of tire slip increases with speed and the sharpness of the turn. This tire slip action causes the actual center of the turn to be considerably ahead of the theoretical turn center (Figure 16-13).

The **slip angle** on different vehicles varies depending on such factors as vehicle weight and type of suspension.

Slip angle is the actual angle of the front wheels during a turn compared to the turning angle of the front wheels with the vehicle at rest.

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Rear Wheel Alignment

Rear Wheel Alignment Diagnosis

Customer complaints that indicate rear wheel alignment problems are the following:

1. The front wheel toe is set correctly and the steering wheel is centered on the alignment rack, but the steering wheel is not centered when the vehicle is driven straight ahead.
2. The steering pulls to one side, but there are no worn suspension parts, defective tires, or improper front suspension alignment angles.
3. The vehicle is not overloaded and there are no worn suspension parts or improper front suspension alignment angles, but tire wear occurs.

Rear wheel camber is the tilt of a line through the center of the rear tire and wheel in relation to the true vertical centerline of the tire and wheel.

Defects That Cause Incorrect Rear Wheel Alignment

These suspension or chassis defects cause incorrect rear wheel alignment:

1. Collision damage that results in a bent frame or distorted unitized body
2. A leaf-spring eye that is unwrapped or spread open
3. Leaf-spring shackles that are broken, bent, or worn
4. Broken leaf springs or leaf spring center bolts
5. Worn rear upper or lower control arm bushings
6. Worn trailing arm bushings or dislocated trailing arm brackets
7. Bent components such as radius rods, control arms, struts, and rear axles

Rear wheel toe is the distance between the front edges of the rear tires in relation to the distance between the rear edges of the rear tires.

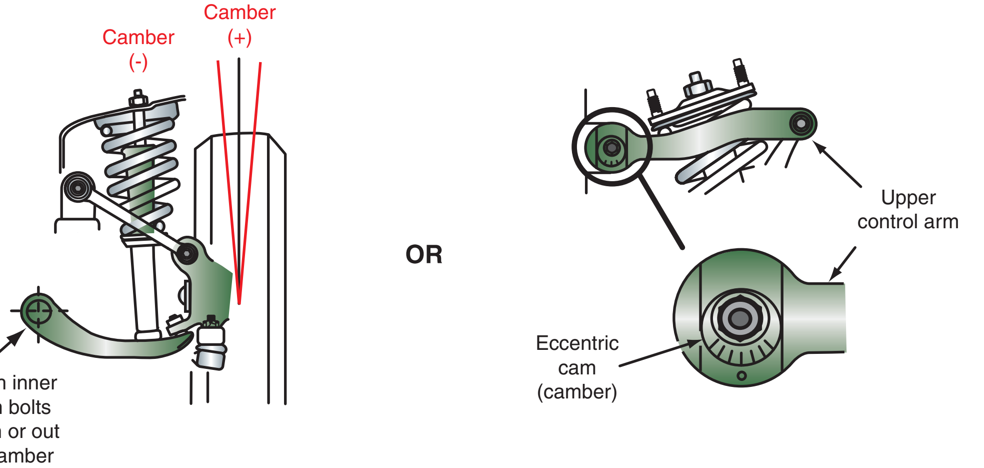

FIGURE 16-14 **Rear wheel camber.**

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Rear Wheel Camber

Many front-wheel-drive vehicles have a slightly negative rear wheel camber that provides improved cornering stability. **Rear wheel camber** is basically the same as front wheel camber (Figure 16-14).

During rear wheel jounce on a multi-link rear suspension system, the camber becomes more positive, and the camber moves toward a negative position during wheel rebound. Because camber changes during wheel jounce, and rebound causes tire tread wear, the rear suspension is designed to minimize camber change during wheel jounce and rebound.

A Bit of History

During a recent October Car Care Month, statistics were compiled from 65 inspection lanes in the United States. During these inspections, 29 percent of the cars failed the tire test. These figures indicate that almost one-third of the vehicles on the road have tire problems, and in many cases these problems create a safety hazard. These figures also tell us there is a tremendous business potential in tire sales, wheel balancing, and wheel alignment. Each time we perform even minor vehicle service the tires should be inspected. This inspection may not only help us increase tire sales and the volume of wheel balancing and alignment service work, but in some cases you may also save the customer's life!

Rear Wheel Toe

On a front-wheel-drive vehicle, driving forces tend to push back the rear wheel spindles. Therefore these rear wheels are designed with zero toe-in or a slight toe-in depending on the vehicle (Figure 16-15). Correct **rear wheel toe** is important to obtain normal tire life.

On a multi-link rear suspension system with the toe adjustment link mounted in a level position, the toe moves toward a toe-in position during wheel jounce or rebound. These toe changes cause rear tire tread wear.

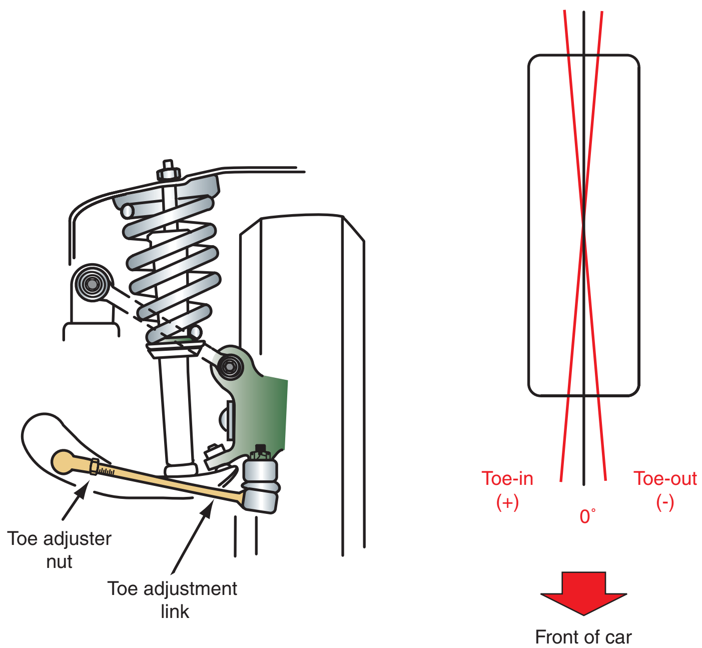


FIGURE 16-15 **Rear wheel toe.**

Summary

- Steering axis inclination (SAI) is the angle of a line through the center of the upper strut mount and lower ball joint in relation to the true vertical centerline of the tire viewed from the front of the vehicle.
- On short-and-long arm front suspension systems, the SAI line runs through the center of the upper and lower ball joints.
- The SAI line is always tilted toward the center of the vehicle.
- The included angle is the sum of the SAI and positive camber angle.
- If the camber is negative, the camber must be subtracted from the SAI angle to obtain the included angle.
- SAI causes the front spindles to move through an arc when the front wheels are steered to the right or left.
- Since the front spindles move through an arc, the chassis lifts as the front wheels are turned. This lifting action helps return the front wheels to the straight-ahead position after a turn.
- SAI also helps maintain the front wheels in the straight-ahead position.
- SAI reduces the need for excessive positive caster.
- SAI is not adjustable. If the SAI does not equal the manufacturer's specifications and the other steering angles are correct, some suspension component, such as a strut tower, is out of place.
- A suspension system with a 0° SAI line would have increased tire wear, greater steering effort, increased stress on suspension and steering components, and excessive road shock and kickback on the steering wheel.
- When the SAI line intersects the true vertical tire centerline at or near the road surface, tire life is improved, stress on steering and suspension components is reduced, steering effort is decreased, and road shock and kickback on the steering wheel are minimized.
- Since excessive positive camber could be used to bring the SAI lines and tire vertical centerlines closer together, SAI reduces the need for excessive positive camber.
- If SAI angles on both sides of the front suspension are unequal, excessive torque steer may occur on hard acceleration, and severe steering pull may be present during hard braking.
- Adjusting camber on some front suspensions creates a corresponding change in SAI angle, whereas on other front suspension systems adjusting the camber does not change the SAI angle.
- Scrub radius is the distance between the SAI line and the true vertical tire centerline at the road surface.
- A front suspension has positive scrub radius when the SAI line contacts the road surface inside the true vertical tire centerline.
- A front suspension has negative scrub radius when the SAI line contacts the road surface outside the true vertical tire centerline.
- If the front tires are larger than the original tires specified by the vehicle manufacturer, a change occurs in scrub radius that may affect steering control.
- The installation of larger than specified front tires may change positive scrub radius to a negative scrub radius.
- Reversing the front rims so they are inside-out results in a significant scrub radius change that adversely affects directional control.
- Wheel setback is a condition where one wheel is moved rearward in relation to the opposite wheel.
- Front wheel toe is the distance between the front edges of the tires compared with the distance between the rear edges of the tires.

Summary

- Toe-in is present when the distance between the front edges of the tires is less than the distance between the rear edges of the tires.
- Toe-out occurs when the distance between the front edges of the tires is greater than the distance between the rear edges of the tires.
- Most front-wheel-drive cars have a slight toe-out setting on the front wheels because drive axle forces tend to move the front wheels to a toe-in position.
- Most rear-wheel-drive cars have a slight toe-in setting because driving forces tend to move the front wheels to a toe-out position.
- The front wheel toe is adjusted with the vehicle at rest so the front wheels are straight ahead when the vehicle is driven.
- Improper toe adjustment results in feathered tire wear.
- Toe-out on turns is the turning angle of the wheel on the inside of the turn compared with the turning angle of the wheel on the outside of the turn.
- When the front wheel on the inside of a turn has turned 20° outward, the front wheel on the outside of the turn may have turned 18°.
- Turning radius is the amount of toe-out on turns.
- Toe-out on turns prevents tire scuffing. This angle is determined by the steering arm design.
- During a turn, centrifugal force causes all the tires to slip a certain amount depending on vehicle speed and the sharpness of the turn.
- Because the tires slip during a turn, the actual vehicle turning center is moved ahead of the theoretical turning center.
- Slip angle is the actual angle of the front wheels during a turn compared with the turning angle of the front wheels with the vehicle at rest.
- The two rear wheel alignment angles are camber and toe.

Terms to Know

Included angle
King pin inclination (KPI)
Negative scrub radius
Positive scrub radius
Rear wheel camber
Rear wheel toe
Scrub radius
Slip angle
Steering axis inclination (SAI)
Toe-in
Toe-out
Toe-out on turns
Turning radius
Wheel setback

Review Questions

Short Answer Essays

1. Define steering axis inclination (SAI).
2. Explain the included angle.
3. Explain how SAI helps to return the steering wheel to the center position after a turn.
4. Define negative scrub radius and positive scrub radius, including the type of suspension system on which each condition is used.
5. Describe front wheel setback.
6. Define toe-in and toe-out.
7. Describe the type of tire tread wear caused by an improper toe setting.
8. Explain the turning angle of each front wheel during a turn.
9. Describe three customer complaints that may indicate rear wheel alignment problems.
10. Describe six defects that may cause incorrect rear wheel alignment.

Fill-in-the-Blanks

1. A 3° difference in the SAI angle on each side of the front suspension may cause _______________ during hard braking.
2. A 3° difference in the SAI angle on each side of the front suspension may cause increased _______________ during hard acceleration.
3. When a front suspension has a positive scrub radius, the SAI line meets the road surface _______________ the true vertical centerline of the tire.

4. A negative scrub radius tends to turn the front wheels _______________ when the car is driven.
5. Most rear-wheel-drive cars have a _______________ scrub radius.
6. The front wheel toe on many rear-wheel-drive cars is adjusted to a slight _______________ setting.
7. When the steering linkage is located at the rear edge of the front tires, sagged front springs _______________ the toe-in.
8. During a turn, the _______________ front wheel turns at a sharper angle.
9. When the steering linkage is positioned at the front edge of the front wheels, driving forces tend to _______________ the steering linkages.
10. During a turn, centrifugal force causes all the tires to slip a certain amount, and the actual center of the turn is shifted _______________ of the theoretical center of the turn.

Multiple Choice

1. When measuring front wheel alignment angles, to calculate the included angle on the left front wheel when the camber on this wheel is positive:
   - A. Add the camber to the toe setting.
   - B. Add the camber to the SAI angle.
   - C. Add the SAI to the caster angle.
   - D. Subtract the SAI from the toe setting.
2. While diagnosing problems related to scrub radius:
   - A. If the SAI line contacts the road surface inside the vertical tire and wheel centerline, the scrub radius is negative.
   - B. Front-wheel-drive cars usually have a negative scrub radius and driving forces move the front wheels outward.
   - C. If the SAI line contacts the road surface outside the tire and wheel vertical centerline, driving forces turn the front wheels outward.
   - D. Larger than specified front tires may change the scrub radius from positive to negative.
3. While diagnosing front wheel toe problems:
   - A. The front wheels are set to a straight-ahead position on most front-wheel-drive cars.
   - B. Driving forces tend to move the front wheels toward a toe-in position on a rear-wheel-drive car.
   - C. Improper toe adjustment may cause feathered wear on the front tire treads.
   - D. Sagged front springs may increase the front wheel toe-out on a short-and-long arm suspension system.
4. While diagnosing and adjusting turning radius:
   - A. When a vehicle is making a left turn, the left front wheel turns at a sharper angle than the right front wheel.
   - B. Improper turning radius may be caused by a bent tie-rod on a short-and-long arm suspension system.
   - C. Improper turning radius may be caused by an improperly positioned rack and pinion steering gear on a front-wheel-drive car.
   - D. Improper turning radius is adjusted by turning an eccentric strut-to-steering-knuckle bolt.
5. When performing a rear wheel alignment, a typical front-wheel-drive car has:
   - A. A zero toe or a slight toe-in.
   - B. A ½° positive camber setting.
   - C. A ½° setback setting on the left rear wheel.
   - D. A 3° positive caster setting on both rear wheels.
6. A front-wheel-drive car has an improper toe-out on turns setting, and a visual check indicates all the steering linkage and suspension components are satisfactory. The most likely cause of this problem is:
   - A. A bent lower control arm.
   - B. A bent front strut.
   - C. A front strut tower that is out-of-position.
   - D. A bent steering arm.

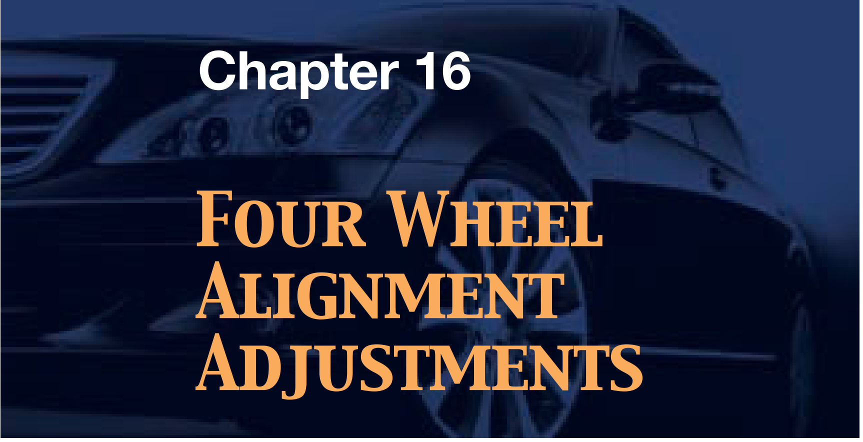
7. All of these statements about SAI and front spindle movement are true EXCEPT:
   A. When the steering wheel is turned, the front spindle movement is parallel to the road surface.
   B. When the SAI angle is increased, the steering wheel returning force is increased.
   C. The SAI angle tends to maintain the wheels in a straight-ahead position.
   D. Greater SAI angle is necessary on front-wheel-drive cars to provide directional stability.
8. All the front alignment angles on a front-wheel-drive car are set to specifications and the steering wheel is centered on the alignment rack, but when the car is driven straight ahead the steering pulls to the right.

   Technician A says the most likely cause of this problem is incorrect rear wheel toe.

   Technician B says the most likely cause of this problem is incorrect rear wheel camber.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B
9. A light-duty truck with a one-piece rear axle housing and a leaf spring rear suspension has excessive toe-out on the left rear wheel and too much toe-in on the right rear wheel. The most likely cause of this problem is:
   A. A broken center bolt in the left rear spring.
   B. Both rear springs are sagged.
   C. A bent rear axle housing.
   D. Worn-out rubber bushings in the shock absorbers.
10. While discussing scrub radius:
    A. Most front-wheel-drive cars have a positive scrub radius.
    B. If the SAI line meets the road surface outside the tire vertical centerline, the scrub radius is positive.
    C. Scrub radius is adjusted by shifting the upper strut tower on a MacPherson strut front suspension.
    D. Incorrect scrub radius may be caused by larger than specified front tires.



Chapter 16

Four Wheel Alignment Adjustments

Upon completion and review of this chapter, you should be able to:

- Adjust front wheel camber on various front suspension systems.
- Adjust front wheel caster on various front suspension systems.
- Correct setback conditions.
- Check and correct front engine cradle position.
- Correct SAI angles that are not within specifications.
- Adjust front wheel toe.
- Center steering wheel.
- Recognize the symptoms of improper rear wheel alignment.
- Diagnose the causes of improper rear wheel alignment.
- Perform rear wheel camber adjustments.
- Perform rear wheel toe adjustments.
- Use a track gauge to measure rear wheel tracking.
- Diagnose rear wheel tracking problems from the track gauge measurements.

Proper front and rear wheel alignment is extremely important because it affects directional stability, tire tread wear, and vehicle safety! Technicians must know how to check front and rear wheel alignment angles and diagnose the causes of steering and alignment problems. It is also essential for technicians to know how to adjust front and rear suspension angles while maintaining vehicle safety. On certain vehicles, some wheel alignment angles are considered non-adjustable by the vehicle manufacturer, but aftermarket suppliers often provide parts kits to provide adjustments on these suspension systems. This chapter provides various adjustment procedures of front and rear suspension alignment angles as summarized in Photo Sequence 29 on page 550.

BASIC TOOLS

Basic technician's tool set

Service manual

Chalk

Wheel Alignment Procedure

The proper procedure for front and rear wheel alignment is important since adjusting one wheel alignment angle may change another angle. For example, adjusting front wheel caster changes front wheel toe. The wheel alignment adjustment procedure is especially critical on four-wheel independent suspension systems. A front wheel adjustment procedure is provided in Figure 16-1, and a typical rear wheel adjustment procedure is given in Figure 16-2. Always follow the wheel alignment procedure in the vehicle manufacturer's service manual. On rear wheel drive vehicles the rear wheel alignment is performed first.

SERVICE TIP: Since rear wheel alignment plays a significant role in aiming or steering the vehicle, the rear wheel alignment should be corrected before adjusting front suspension angles. The rear wheel camber, toe, and thrust line must be within specifications before adjusting the front suspension angles.

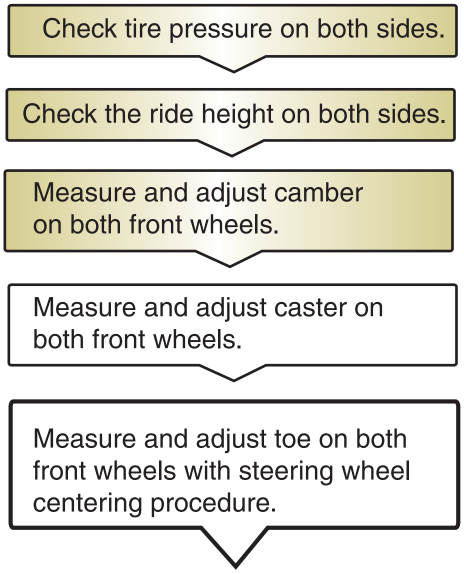


FIGURE 16-1 **Front wheel alignment adjustment procedure.**

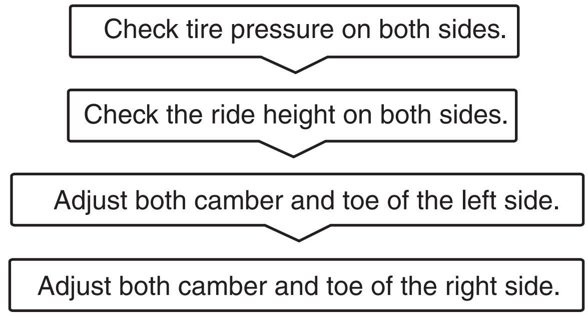


FIGURE 16-2 **Rear wheel alignment adjustment procedure.**

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Chapter 15, page 345

Camber Adjustment

Shims

A **camber adjustment** is usually a shim-type or eccentric cam-type mechanism that is used to correct the camber angle on front or rear wheels.

Various methods are provided by car manufacturers for camber adjustment. Some car manufacturers provide a shim-type **camber adjustment** between the upper control arm mounting and the inside of the frame (Figure 16-3). In this type of camber adjustment, increasing the shim thickness moves the camber setting to a more negative position, whereas decreasing shim thickness changes the camber toward a more positive position. Shims of equal thickness should be added or removed on both upper control arm mounting bolts to change the camber setting without affecting the caster setting.

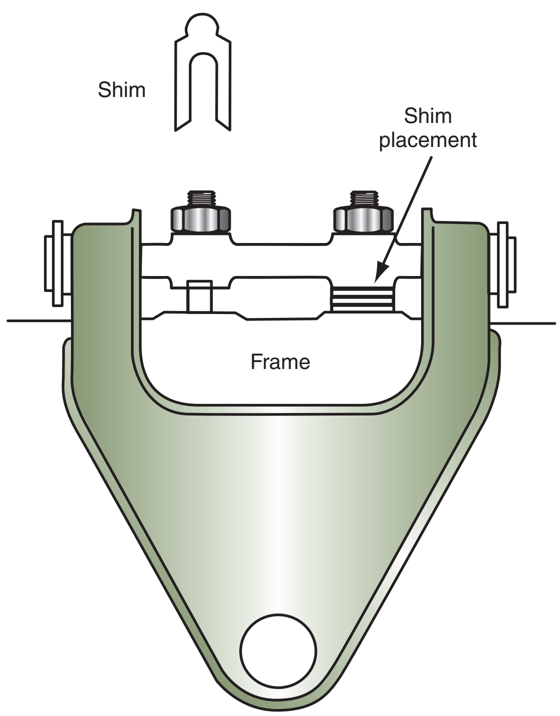

FIGURE 16-3 **Shim-type camber adjustment between upper control arm mounting and the inside of the frame.**

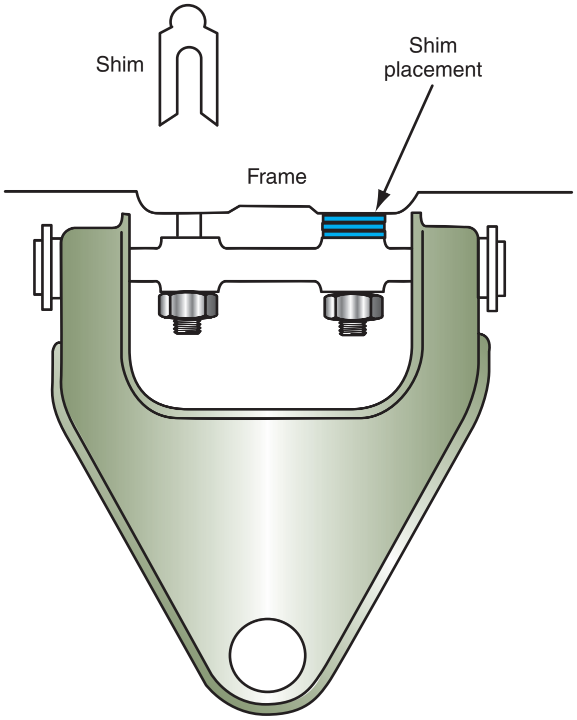

FIGURE 16-4 **Shim-type camber adjustment between upper control arm mounting and the outside of the frame.**

Other vehicle manufacturers provide a shim-type camber adjustment between the upper control arm mounting and the outside of the frame (Figure 16-4). On this shim-type camber adjustment, increasing the shim thickness increases positive camber.

Older vehicles have shim-type camber adjustments, but newer vehicles have eccentric cams for this adjustment.

Eccentric cams are out-of-round pieces of metal mounted on a retaining bolt with the shoulder of the cam positioned against a component. When the cam is rotated, the component contacting the cam shoulder is moved.

Eccentric Cams

Some vehicles have **eccentric cams** on the inner ends of the upper control arm to provide camber adjustment (Figure 16-5), whereas other suspension systems have eccentric cams on the inner ends of the lower control arms (Figure 16-6). If the original cam adjustment on the inner ends of the upper control arms does not provide enough camber adjustment, aftermarket upper control arm shaft kits are available that provide an extra 1 1/2° of camber adjustment (Figure 16-7). The suspension adjustments shown in Figures 16-3 through 16-7 are used on rear-wheel-drive cars with short-and-long arm front suspension systems.

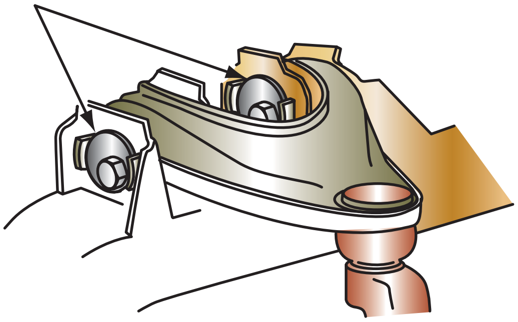

FIGURE 16-5 **Cam adjustment on the inside ends of the upper control arm.**

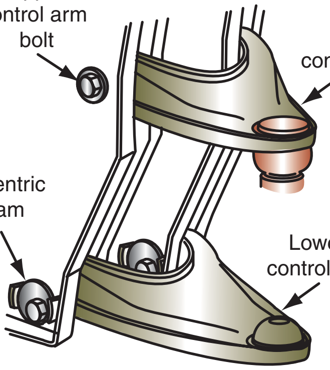

FIGURE 16-6 **Cam adjustment on the inner ends of the lower control arms.**

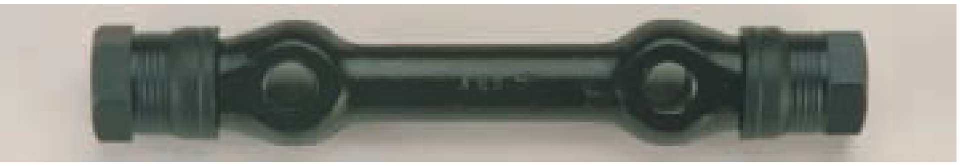

FIGURE 16-7 **Upper control arm shaft kit provides an extra 1 1/2° camber adjustment.**

Some MacPherson strut front suspension systems on front-wheel-drive cars have a cam on one of the steering-knuckle-to-strut bolts to adjust camber (Figure 16-8). Aftermarket camber adjustment kits that provide 2-1/2° of camber adjustment are available for many MacPherson strut suspension systems (Figures 16-9 and 16-10). Similar camber adjustment kits are available for many cars with MacPherson strut front suspension systems. On some double-wishbone front suspension systems, a graduated cam on the inner end of the lower control arm provides a camber adjustment (Figure 16-11).

On late model Ford F-150 light-duty truck 4 x 2 front suspension systems, an alignment plate is installed on the upper control arm attaching nuts when the vehicle is manufactured (Figure 16-12). If a camber or caster adjustment is required, remove the control arm attaching nuts one at a time and install eccentric cams behind the adjusting nuts (Figure 16-13). Turn the eccentric cams equally on the front and rear upper control arm attaching nuts to adjust the camber. To increase the positive caster, move the front of the upper control arm outboard and move the rear of the upper control arm inboard (Figure 16-14). If it is necessary to decrease the positive caster, move the front of the upper control arm inboard and move the rear of the upper control arm outboard (Figure 16-15). These front suspension systems

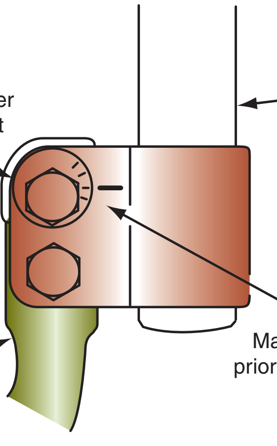

FIGURE 16-8 **Eccentric steering knuckle-to-strut camber adjusting bolt, MacPherson strut front suspension.**

FIGURE 16-9 **Camber adjustment kits provide 2 1/2° camber adjustment on some General Motors cars.**

FIGURE 16-10 **Camber adjustment kits provide 2 1/2° camber adjustment on some vehicles.**

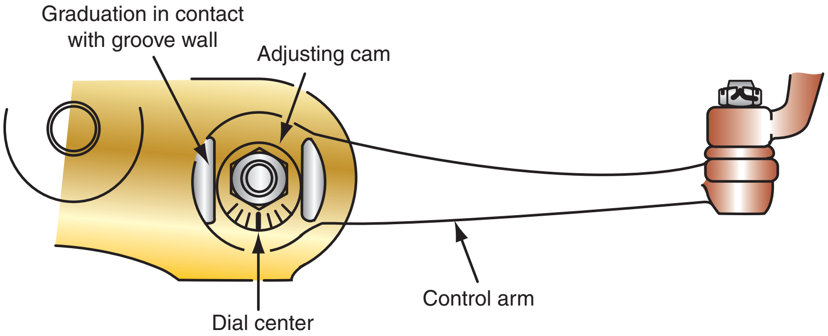

FIGURE 16-11 **Camber adjustment double-wishbone front suspension.**

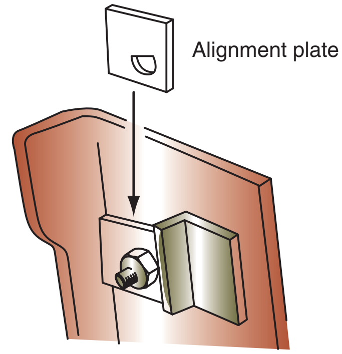

FIGURE 16-12 **Alignment plate on upper control arm attaching nut.**

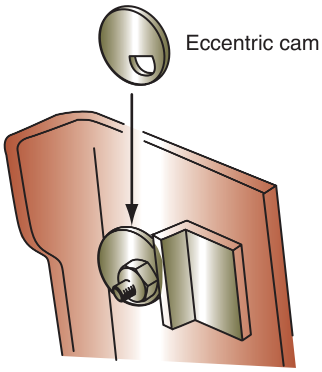

FIGURE 16-13 **Eccentric cam installed behind upper control arm attaching nut.**

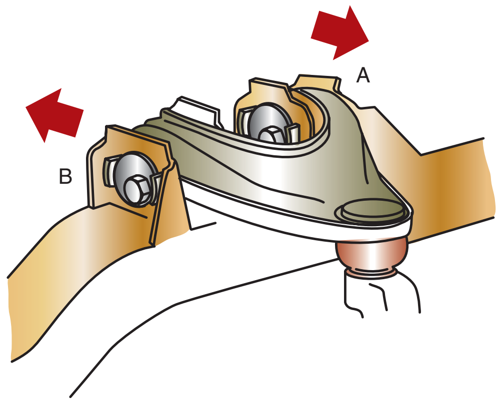

FIGURE 16-14 **To increase the positive caster, move the front of the upper control arm (A) outboard and move the rear of the upper control arm (B) inboard.**

also have eccentric cams on the lower control arm attaching bolts (Figure 16-16). However, these eccentric cams are only for factory use, and they must not be adjusted in service. When removing the lower control arms, always mark the eccentric cams on the attaching bolts and reinstall these cams in their original position.

In some front suspension systems such as on the PT Cruiser, eccentric cams are not installed to provide a camber adjustment. In these suspension systems, the manufacturer supplies slightly undersize strut bracket-to-knuckle attaching bolts which allow a 2° camber adjustment on each side of the front suspension. If a camber adjustment is required, remove

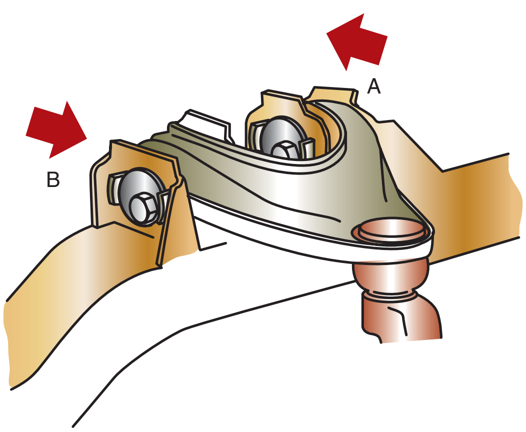

FIGURE 16-15 **To decrease the positive caster move the front of the upper control arm (A) inboard and move the rear of the upper control arm (B) outboard.**

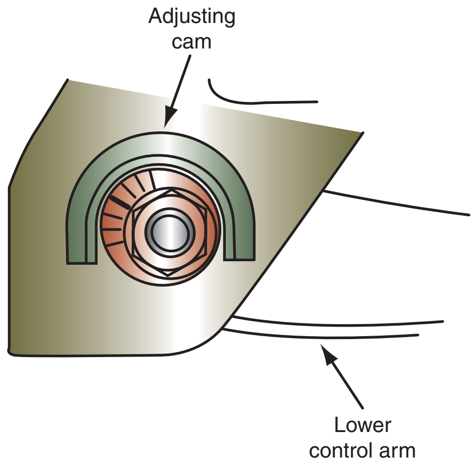

FIGURE 16-16 **Factory-set eccentric cam on lower control arm attaching bolts.**

the strut bracket-to-knuckle attaching bolts one at a time and install the undersize bolts. Install the nuts snugly on these bolts, but do not torque the nuts. Install each bolt from the rear of the knuckle. With the car on a wheel alignment rack, pull or push the top of the tire to obtain the specified camber. After the camber is set to specifications, tighten the strut bracket-to-knuckle attaching bolts to the specified torque.

Slotted Strut Mounts and Frames

On some MacPherson strut front suspension systems, the upper strut mounts may be loosened and moved inward or outward to adjust camber (Figure 16-17). Other MacPherson strut front suspension systems do not provide a camber adjustment. For these cars, aftermarket manufacturers sell slotted upper strut bearing plates that provide camber adjustment capabilities (Figure 16-18). If the front wheel camber adjustment is not correct, check for worn components such as ball joints or upper strut mounts. Also check the engine cradle mounts. Since the inner ends of the lower control arms are attached to the engine cradle on many front-wheel-drive cars, a cradle that is out of position may cause improper camber readings.

For example, if the vehicle has been impacted on the left-front corner in a collision, the cradle may be shifted to the right. This action moves the bottom of the left-front wheel inward and the bottom of the right-front wheel outward. Therefore, the left-front wheel has excessive positive camber and the right-front wheel has too much negative camber. If the vehicle has been impacted on the left-front corner, the cradle may be squashed to some extent with the left side being moved toward the right side without moving the right side of the cradle out of position. In this case the left front wheel has excessive positive camber, and the side-to-side cradle measurements are less than specified.

A camber plate is locked in place with a pop rivet on some upper strut mounts. The pop rivet may be removed to release the camber plate (Figure 16-19). After the upper strut mount bolts are loosened, the mount may be moved inward or outward to adjust the camber. When the camber is adjusted to the vehicle manufacturer's specification, the strut mount bolts should be tightened to the correct torque and a new pop rivet installed.

On some short-and-long arm front suspension systems, the bolt holes in the frame are elongated for the inner shaft on the upper control arm. When these bolts are loosened, the upper control arm may be moved inward or outward to adjust camber (Figure 16-20).

When a camber adjustment is required on some MacPherson strut front suspensions, the vehicle manufacturer recommends removing the strut-to-steering knuckle retaining bolts and removing the strut from the knuckle. A round file is then used to elongate the lower bolt opening in the strut (Figure 16-21). Reinstall the strut and retaining bolts, but leave the nuts slightly loose on the bolts. With the vehicle in the proper position on the wheel aligner rack, grasp the tire and move the top of the tire inward or outward to obtain the desired camber adjustment, and then tighten the nuts on the strut-to-knuckle bolts to the specified torque.

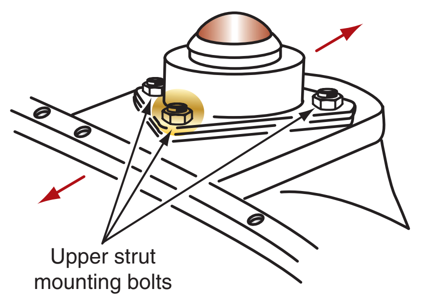

FIGURE 16-17 **The upper strut mounting bolts can be loosened and the mount moved inward or outward to adjust camber on some MacPherson strut front suspension systems.**

FIGURE 16-18 **Slotted upper strut bearing plates provide camber adjustment on some MacPherson strut front suspension systems.**

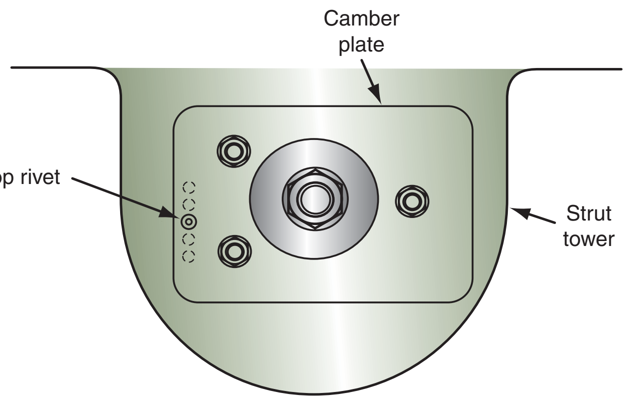

FIGURE 16-19 **Upper strut mount with camber plate and rivet, modified MacPherson strut front suspension.**

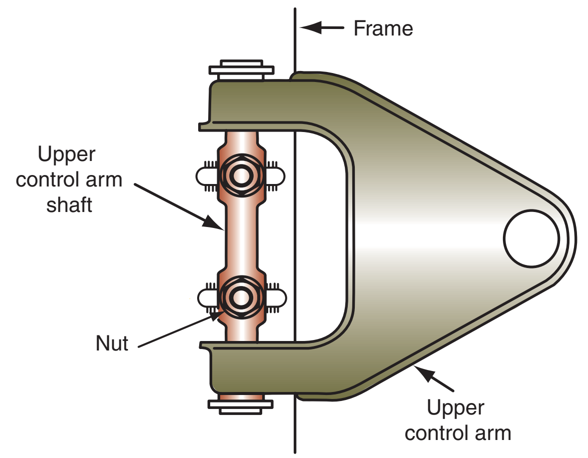

FIGURE 16-20 **Elongated bolt holes for upper control arm shaft bolts provide camber adjustment on some short-and-long arm front suspension systems.**

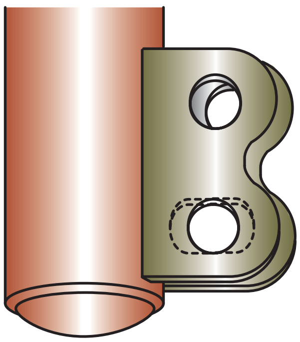

FIGURE 16-21 **Elongated lower strut-to-knuckle bolt hole for camber adjustment.**

Special Adjustment Bolts

On other vehicles such as the 2005 Dodge Magnum, the vehicle manufacturer recommends loosening the cradle mounts and shifting the cradle to provide minor camber and/or caster adjustments (Figure 16-22). If the desired camber adjustment cannot be obtained by shifting the cradle, the vehicle manufacturer provides an adjustment bolt package for camber and caster adjustment. These bolts are designed to replace the inboard bolts in the lower control arm and tension strut. To adjust camber use both bolts, and to adjust caster only use a replacement bolt in the tension strut.

The wheel alignment adjustment bolts have offset grooves cut into the length of the bolts (Figure 16-23). The grooves in the adjustment bolts force the bolt to be installed in one or two ways depending on whether more positive or negative camber is required. The bolt grooves work with “bat wing” holes in the lower control arm and tension strut bushings. The original

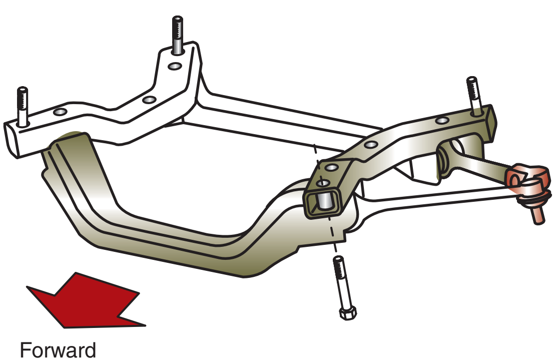

FIGURE 16-22 **Loosening cradle mounting bolts and shifting the cradle to perform minor camber adjustments.**

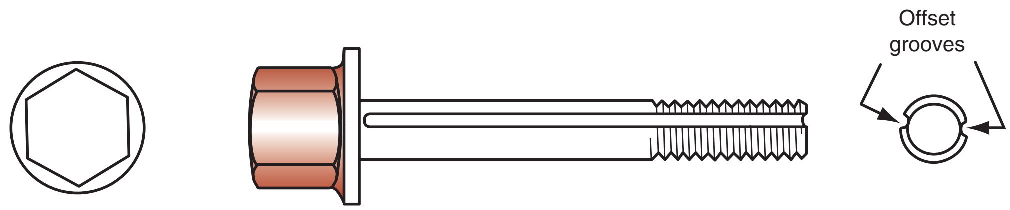

FIGURE 16-23 **Camber/caster adjustment bolt with offset grooves.**

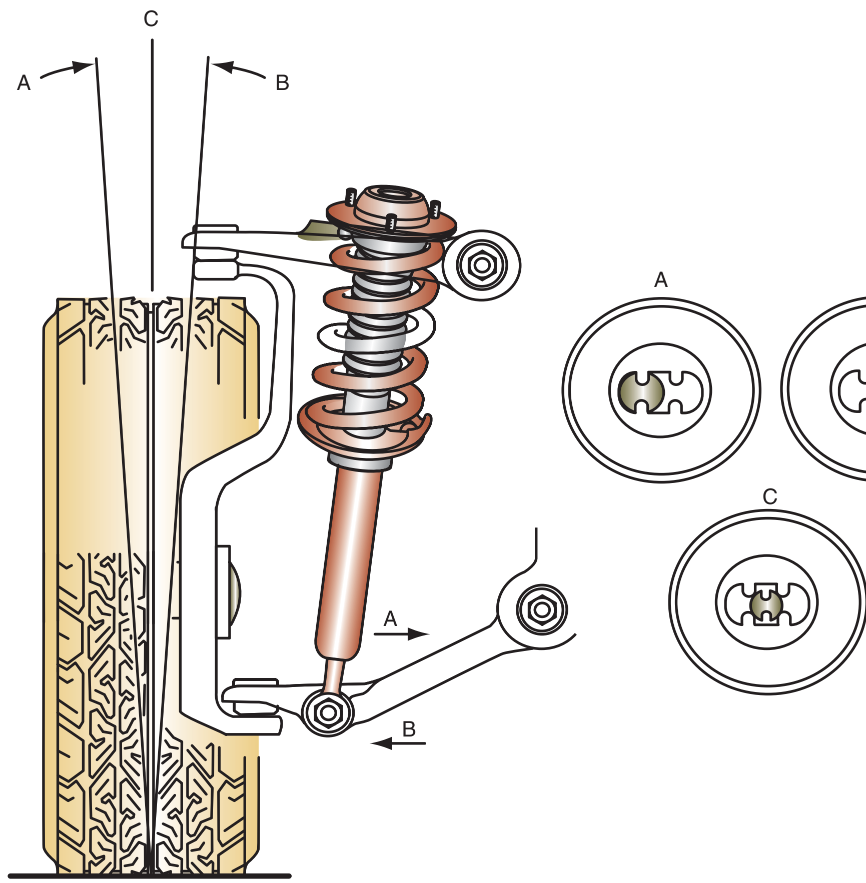

FIGURE 16-24 **Adjustment bolt positions in tension strut or lower control arm bushing to provide camber adjustment.**

SERVICE TIP: The bolt in the lower control arm bushing must be installed from the rear and the tension strut bushing bolt must be installed from the front to avoid contact with other suspension components.

CAUTION: After an adjustment bolt is installed, do not attempt to rotate the bolt. This action will damage the "bat wing" in the control arm or tension strut bushing.

non-grooved bolt is installed between the "bat wings" in the center of the tension strut or lower control arm bushing opening (Figure 16-24, view C). After the original bolt is removed from the tension strut or control arm, move the control arm or tension strut inward or outward as desired. To provide more positive camber, install the adjustment bolt grooves in the "bat wings" (Figure 16-24, view A). The adjustment bolts provide an average of 3° camber adjustment in either direction. Always install a washer under the head of the bolt. Installing the adjustment bolts in the "bat wings" (Figure 16-24, view b) provides more negative camber. After an adjustment bolt is installed, hold the head of the bolt with the proper size tool, and tighten the nut to the specified torque.

To adjust the front wheel caster, follow the same procedure, but install the adjustment bolt only in the tension strut.

Special Tools for Camber Adjustment

Some vehicle manufacturers provide a special tool for adjusting front wheel camber and caster. This tool has threaded projections on each end extending at a right angle from a turnbuckle in the center of the tool. When the turnbuckle is rotated, the tool is lengthened or shortened. The tool is installed into openings in the lower control arm and the chassis (Figure 16-25).

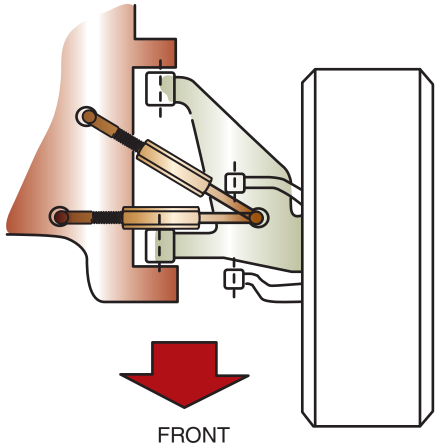

FIGURE 16-25 **Tool installed in lower control arm and chassis openings to adjust camber/caster.**

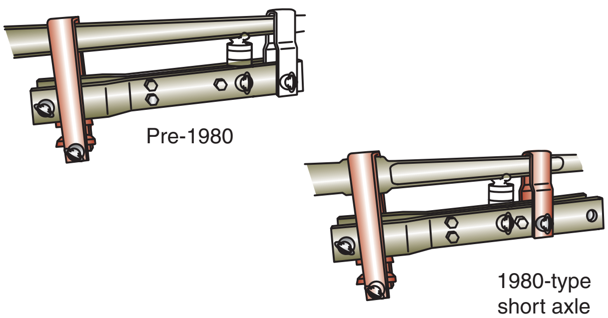

FIGURE 16-26 **Adjusting camber to a more positive setting, twin I-beam front suspension.**

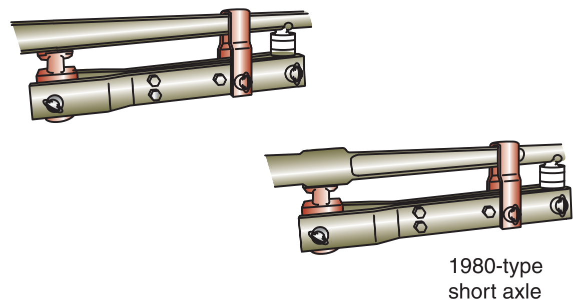

FIGURE 16-27 **Adjusting camber to a more negative setting, twin I-beam front suspension.**

After the bolt is loosened in the inner end of the control arm, the tool can be lengthened or shortened to adjust the camber and/or caster.

Camber Adjustment on Twin I-Beam Front Suspension System

On twin I-beam front suspension systems, a special clamp-type bending tool with a hydraulic jack is used to bend the I beams and change the camber setting. On a twin I-beam front suspension, the clamp and hydraulic jack must be positioned properly to adjust the camber to a more positive setting (Figure 16-26) or a more negative setting (Figure 16-27).

CAUTION: Some vehicle manufacturers do not recommend bending I beams and other suspension components.

Caster Adjustment Procedure

Strut Rod Length Adjustment

On some suspension systems, the nuts on the forward end of the strut rod may be adjusted to lengthen or shorten the strut rod, which changes the caster setting (Figure 16-28). Shorten the strut rod to increase the positive caster.

Eccentric Cams

The same eccentric cams on the inner ends of the upper or lower control arms may be used to adjust camber or caster (Figure 16-29). If an eccentric bushing in the outer end of the upper control arm is rotated to adjust camber, this same eccentric also adjusts caster. On some double-wishbone front suspension systems, the pivot adjuster mounting bolt nuts must be loosened under the compliance pivot, and the graduated cam may then be rotated to adjust caster (Figure 16-30).

SERVICE TIP: The vehicle manufacturer does not recommend bending the I beams to adjust front wheel camber. However, this procedure is suggested by some equipment manufacturers.

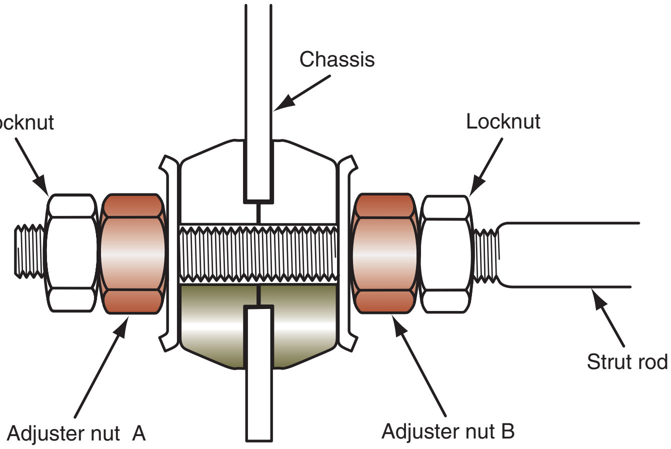

FIGURE 16-28 **Strut rod nuts can be adjusted to lengthen or shorten the strut rod to adjust caster.**

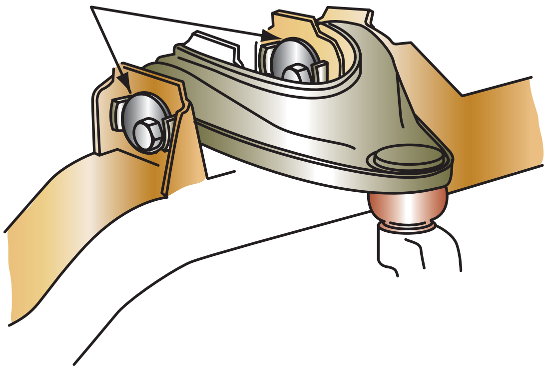

FIGURE 16-29 **Eccentric cams on the inner ends of the upper or lower control arms can be used to adjust camber and caster.**

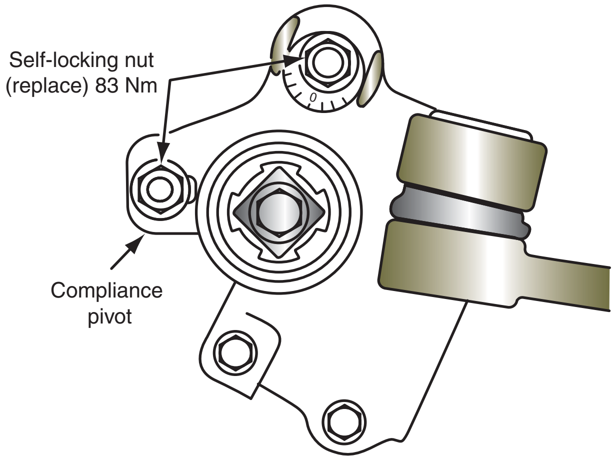

FIGURE 16-30 **Graduated cam for caster adjustment, double-wishbone front suspension.**

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A strut rod may be called a radius rod.

Slotted Strut Mounts and Frames

If a **caster adjustment** is required and the suspension does not have an adjustment for this purpose, check for worn components such as upper strut mounts and ball joints. Also check the engine cradle mounts. Since the inner ends of the lower control arms are attached to the engine cradle on many front-wheel-drive cars, a cradle that is out-of-position may cause improper caster readings.

The slots in the frame at the upper control arm shaft mounting bolts provide camber and caster adjustment. If the upper strut mount is adjustable on a MacPherson strut suspension, the mount retaining bolts may be loosened and the mount moved forward or rearward to adjust caster.

When a caster adjustment is necessary, some vehicle manufacturers recommend removing the upper strut mount bolts and elongating the bolt hole openings in the strut tower with a round file to provide a caster adjustment (Figure 16-31).

WARNING: After any alignment angle adjustment, always be sure the adjustment bolts are tightened to the vehicle manufacturer's specified torque. Loose

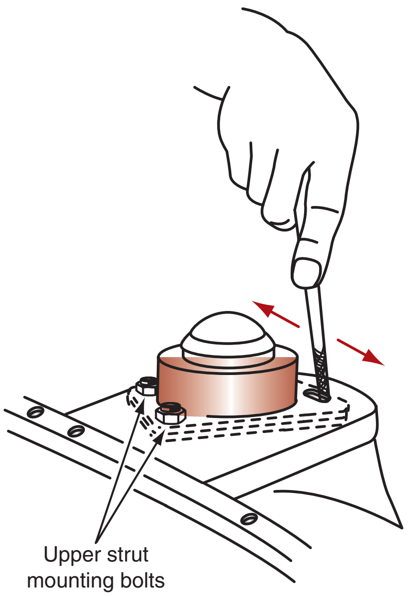

FIGURE 16-31 **Elongating upper strut mount bolt openings to provide caster adjustment.**

suspension adjustment bolts will result in improper alignment angles, steering pull, and tire wear. Loose suspension adjustment bolts may also cause reduced directional stability, which could result in a vehicle accident and possible personal injury.

Caster Adjustment on Twin I-Beam Front Suspension Systems

WARNING: Improper use of bending equipment may result in personal injury. Always follow the equipment and vehicle manufacturer's recommended procedures.

The same bending tool and hydraulic jack may be used to adjust camber and caster on twin I-beam front suspension systems. This equipment is installed on the radius rods connected from the I beams to the chassis to adjust caster. If the hydraulic jack is placed near the rear end of the radius rod and the clamp arm is positioned over the center area of this rod, the rod is bent downward in the center when the jack is operated (Figure 16-32). This bending action tilts the I beam and caster line rearward to increase positive caster.

Aftermarket parts manufacturers supply a special radius arm bushing to provide a caster adjustment on some twin I-beam front suspension systems (Figure 16-33).

SPECIAL TOOLS

Twin I-beam radius rod bending tool

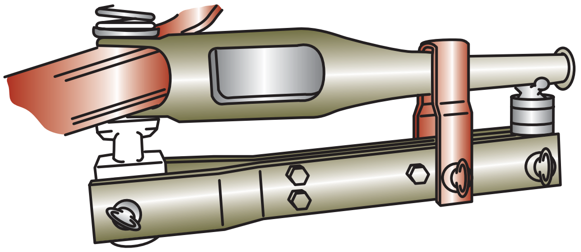

FIGURE 16-32 **Hydraulic jack and bending tool positioned on the radius rod to increase positive caster on a twin I-beam front suspension.**

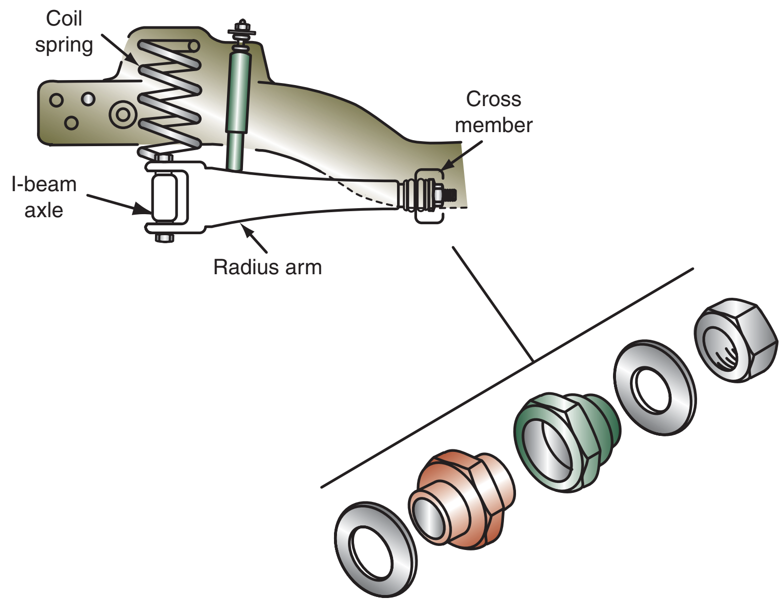

FIGURE 16-33 **Radius arm bushing for caster adjustment on some twin I-beam suspension systems.**

Setback Measurement and Correction Procedure

Setback is the distance that one wheel is moved rearward in relation to the opposite wheel.

Computer wheel aligners have **setback** measuring capabilities on the front wheels. These aligners automatically display setback angles with the other front suspension alignment angles. If a front-wheel-drive vehicle has experienced collision damage on the left front, the left side of the cradle or subframe may be driven rearward (Figure 16-34). This type of collision damage also moves the bottom of the left front strut rearward to a setback condition and shifts the caster to a negative position.

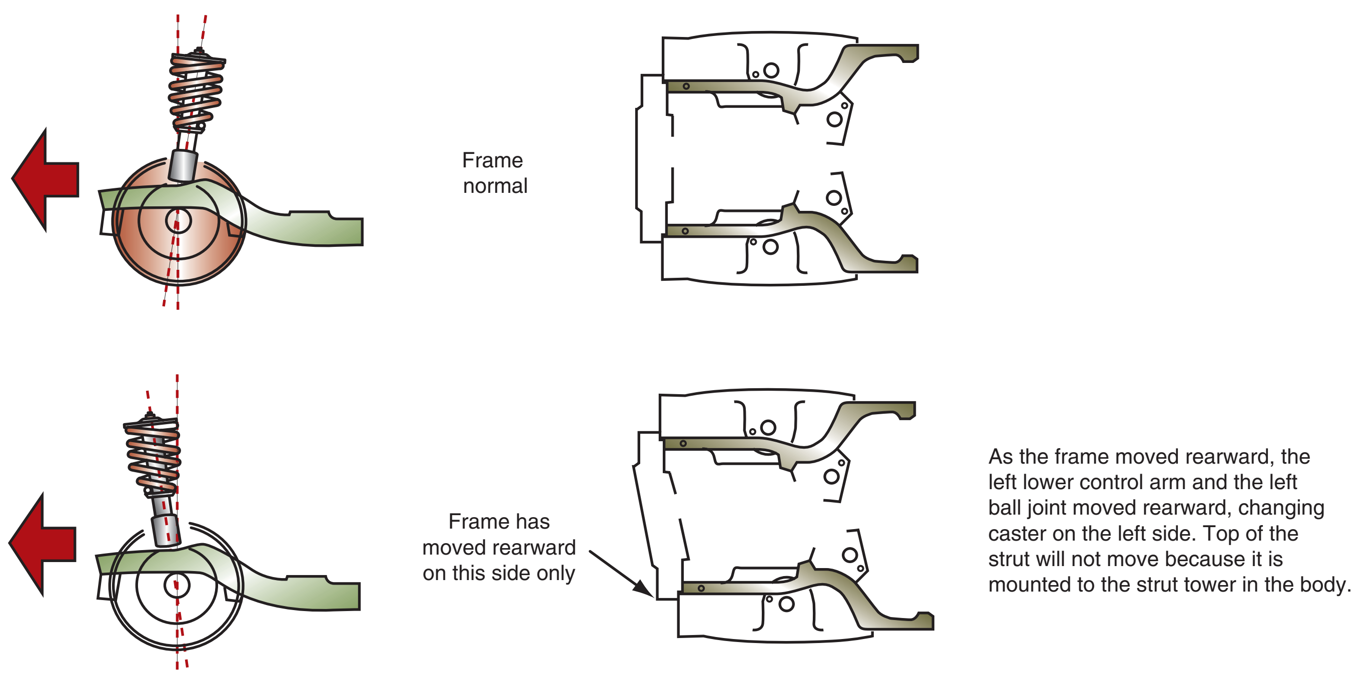

FIGURE 16-34 **Collision damage on the left front moves the cradle and strut rearward to a setback condition and shifts the caster to a negative position.**

WARNING: Prior to any service operation where the body is going to be moved in relation to the cradle or subframe, the intermediate shaft on the rack and pinion gear must be disconnected. If this shaft is not disconnected, it may be damaged, resulting in loss of steering control, serious vehicle damage, and personal injury.

CAUTION:
If the engine cradle has to be removed or loosened, the engine support fixture must hold the engine in the normal position to prevent damage to the fan shroud, power steering hoses, and othe components.

With this type of collision damage, it may be possible to adjust the caster back to the specified setting, but that does not correct the setback problem. If the caster is adjusted and the setback problem is ignored, the steering may pull to one side while driving straight ahead, especially if the setback condition is severe. The cradle must be straightened and the unitized body must be pulled back to the original measurements to correct this problem. A severely bent, distorted cradle should be replaced.

Collision damage may push a front cradle sideways. This condition may increase the positive camber on one side of the car and move the camber toward a negative position on the opposite side. When this condition is encountered, always inspect and correct the cradle position. If the camber is adjusted in this situation, the steering will not provide proper directional control.

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Prior to cradle removal, an engine support fixture must be installed to support the engine and transaxle (Figure 16-35). The engine support fixture must hold the engine in the original position to prevent damage to the power steering hoses or other components.

Before the body is moved in relation to the cradle or subframe, the intermediate shaft on the rack and pinion steering gear must be disconnected to prevent damage to this shaft. Remove all the engine and transaxle mount bolts in the cradle, plus the cradle retaining bolts and insulators to remove the cradle. Perform the front underbody measurements with a tram gauge (Figure 16-36), and pull the unitized body back to these specifications. This pulling operation is usually done in an automotive body shop rather than an automotive repair shop.

The cradle must be restored to the specified measurements (Figure 16-37). Inspect all cradle insulators and replace any that are damaged, oil soaked, or worn. When the cradle

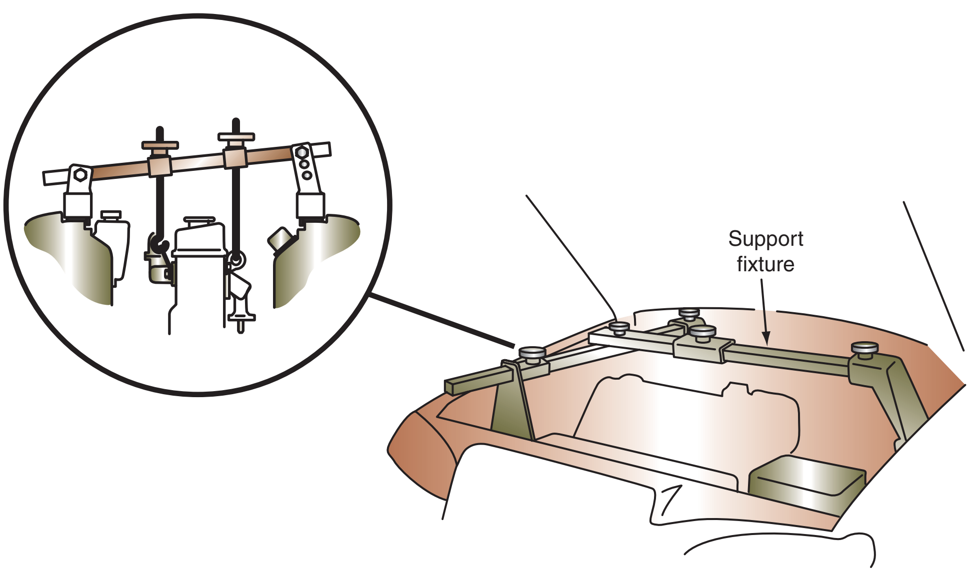

FIGURE 16-35 **Engine support fixture installed to support engine and transaxle prior to cradle removal.**

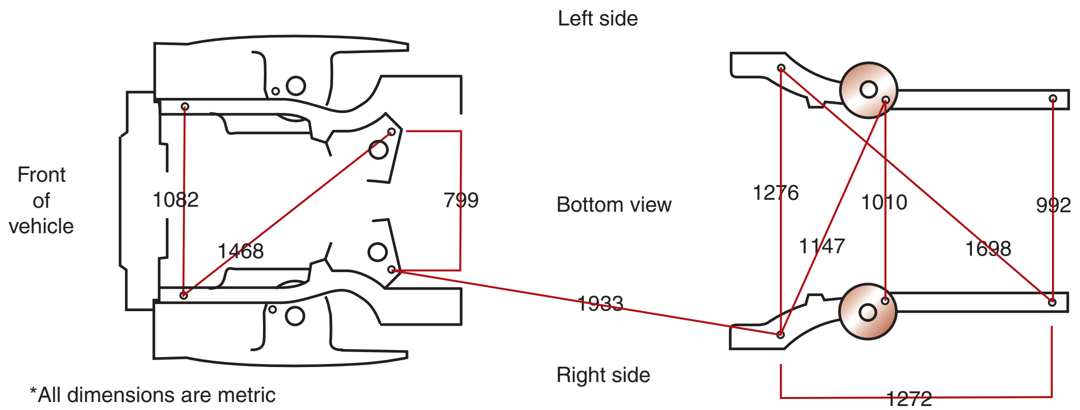

FIGURE 16-36 **Front and rear underbody measurements.**

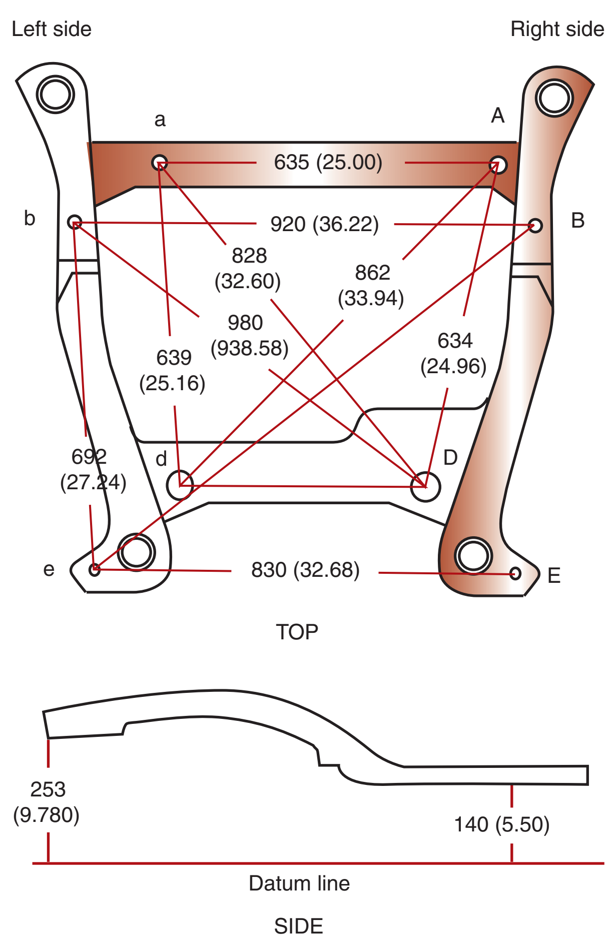

FIGURE 16-37 **Front cradle measurements.**

is replaced, all the insulators must be installed properly, and all the cradle bolts should be aligned with the bolt holes in the body. Alignment hole A in the cradle must be perfectly aligned with the matching alignment hole in the body (Figure 16-38). Observing this alignment hole is a quick way to check cradle position.

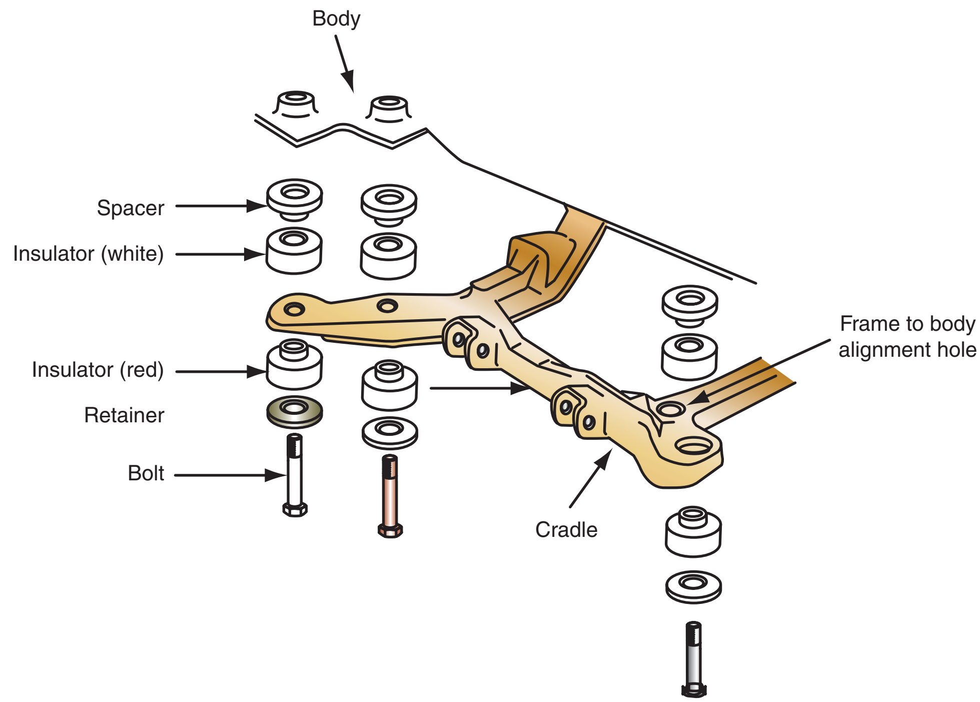

FIGURE 16-38 **Cradle insulators and alignment holes in cradle and body.**

Steering Axis Inclination (SAI) Correction Procedure

Steering axis inclination (SAI) is not considered adjustable. If the SAI is not within specifications, the upper strut tower may be out of position, the lower control arm may be bent, or the center cross member, or cradle, could be shifted. In most cases, these defects are caused by collision damage. When the SAI angle is correct, but the camber and included angle are less than specified, the strut or spindle may be bent. The difference in the included angles on the front wheels must not exceed 1°.

When the SAI is not within specifications, steering pull may occur while braking or accelerating and steering may be erratic on road irregularities.

The **steering axis inclination (SAI)** line is an imaginary line through the centers of the upper and lower ball joints, or through the center of the lower ball joint and the upper strut mount. The SAI angle is the angle between the SAI line and the true vertical centerline of the tire and wheel.

Toe Adjustment

WARNING: Do not heat tie-rod sleeves to loosen them. This action may weaken the sleeves, resulting in sudden sleeve failure, loss of steering control, personal injury, and vehicle damage.

WARNING: Do not use a pipe wrench to loosen tie-rod sleeves. This tool may crush and weaken the sleeve, causing sleeve failure, loss of steering control, personal injury, and vehicle damage. A tie-rod rotating tool must be used for this job.

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When a front wheel toe adjustment is required, apply penetrating oil to the tie-rod adjusting sleeves and sleeve clamp bolts. Loosen the tie-rod adjusting sleeve clamp bolts enough to allow the clamps to partially rotate. One end of each tie-rod sleeve contains a right-hand thread; the opposite end contains a left-hand thread. These threads match the threads on

SPECIAL TOOLS
Tie-rod sleeve rotating tool

Total toe is the sum of the toe settings on the front wheels.

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the tie-rod and outer tie-rod end. When the tie-rod sleeve is rotated, the complete tie-rod, sleeve, and tie-rod end assembly is lengthened or shortened. Use a tie-rod sleeve rotating tool to turn the sleeves until the toe-in on each front wheel is equal to one-half the **total toe** specification (Figure 16-39).

After the **toe-in** adjustment is completed, the adjusting sleeve clamps must be turned so the openings in the clamps are positioned away from the slots in the adjusting sleeves (Figure 16-40). Replace clamp bolts that are rusted, corroded, or damaged, and tighten these bolts to the specified torque.

On some rack and pinion steering gears, the tie-rod locknut is loosened and the tie-rod is rotated to adjust toe on each front wheel (Figure 16-41). Prior to rotating the tie-rod, the small outer bellows boot clamp should be removed to prevent it from twisting during tie-rod rotation. After the toe-in adjustment, the tie-rod locknut must be torqued to specifications, and the small bellows boot clamp must be reinstalled.

On other rack and pinion steering gears, the tie-rod and outer tie-rod end have internal threads, and a threaded adjuster is installed in these threads. One end of the adjuster has a

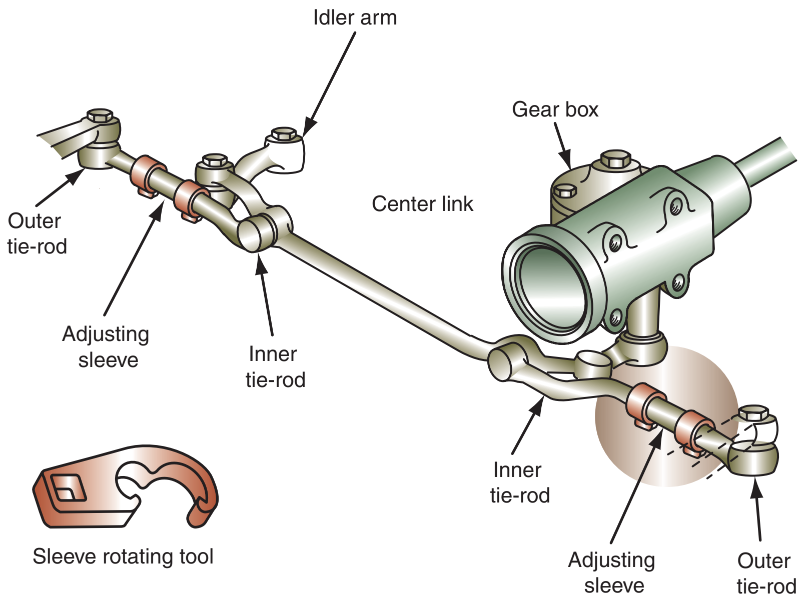

FIGURE 16-39 **Rotating toe-rod sleeves to adjust front wheel toe.**

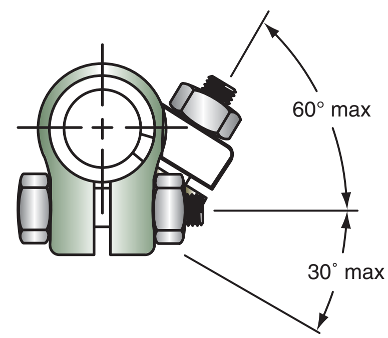

FIGURE 16-40 **Proper tie-rod adjusting sleeve and clamp position.**

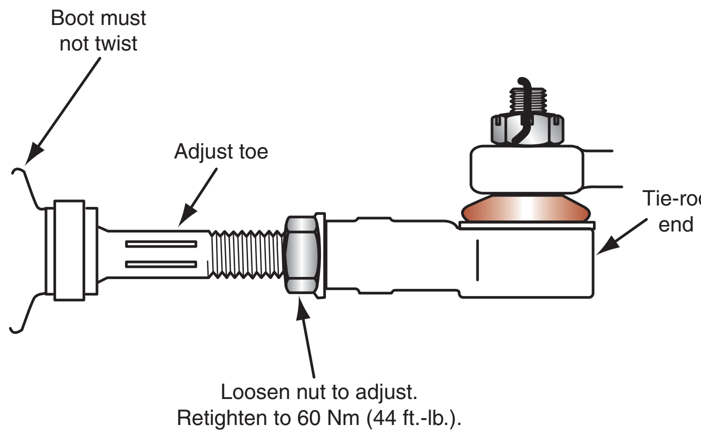

FIGURE 16-41 **Rotating tie-rod to adjust the toe on a rack and pinion steering gear.**

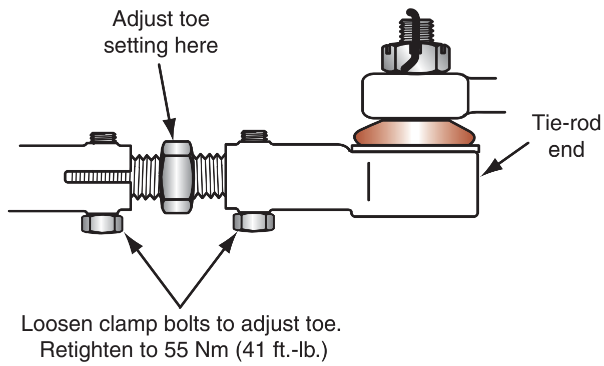

FIGURE 16-42 **Rack and pinion steering gear with externally threaded toe adjuster and internal threads on the tie-rod and outer tie-rod end.**

right-hand thread, and the opposite end has a left-hand thread. Matching threads are located in the outer tie-rod end and tie-rod. Clamps on the outer tie-rod end and tie-rod secure these components to the adjuster. A hex-shaped nut is designed into the center of the adjuster (Figure 16-42). After the clamps are loosened, an open-end wrench is placed on this hex nut to rotate the adjuster and change the toe setting.

When the toe-in adjustment is completed, the toe must be set within the manufacturer's specifications with the steering wheel in the centered position. If the steering wheel is not centered, a centering adjustment is required.

Manual Steering Wheel Centering Procedure

Road test the vehicle and determine if the steering wheel spoke is centered when the vehicle is driven straight ahead.

If steering wheel centering is necessary, follow this procedure:

1. Lift the front end of the vehicle with a hydraulic jack and position safety stands under the lower control arms. Lower the vehicle onto the safety stands and place the front wheels in the straight-ahead position.
2. Use a piece of chalk to mark each tie-rod sleeve in relation to the tie-rod, and loosen the sleeve clamps (Figure 16-43).
3. Position the steering wheel spoke in the position it was in while driving straight ahead during the road test. Turn the steering wheel to the centered position and note the direction of the front wheels.
4. If the steering wheel spoke is low on the left side while driving the vehicle straight ahead, use a tie-rod sleeve rotating tool to shorten the left tie-rod and lengthen the right tie-rod (Figure 16-44). One-quarter turn on a tie-rod sleeve moves the steering wheel position approximately one inch. Turn the tie-rod sleeves the proper amount to bring the steering wheel to the centered position. For example, if the steering wheel spoke is two inches off-center, turn each tie-rod sleeve one-half turn.
5. If the steering wheel spoke is low on the right side while driving the vehicle straight ahead, lengthen the left tie-rod and shorten the right tie-rod.
6. Mark each tie-rod sleeve in its new position in relation to the tie-rod. Be sure the sleeve clamp openings are positioned properly, as indicated earlier in this chapter. Tighten the clamp bolts to the specified torque.
7. Lift the front chassis with a floor jack and remove the safety stands. Lower the vehicle onto the shop floor, and check the steering wheel position during a road test.

SERVICE TIP:
The most accurate check of a properly centered steering wheel is while driving the vehicle straight ahead during a road test.

SERVICE TIP:
Some computer wheel aligners have a steering wheel centering display that provides an easier method of steering wheel centering compared to the manual method.

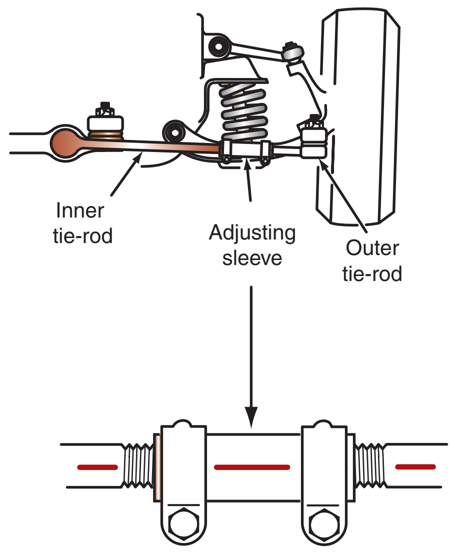

FIGURE 16-43 **Marking toe-rod sleeves in relation to the tie-rods and outer tie-rod ends.**

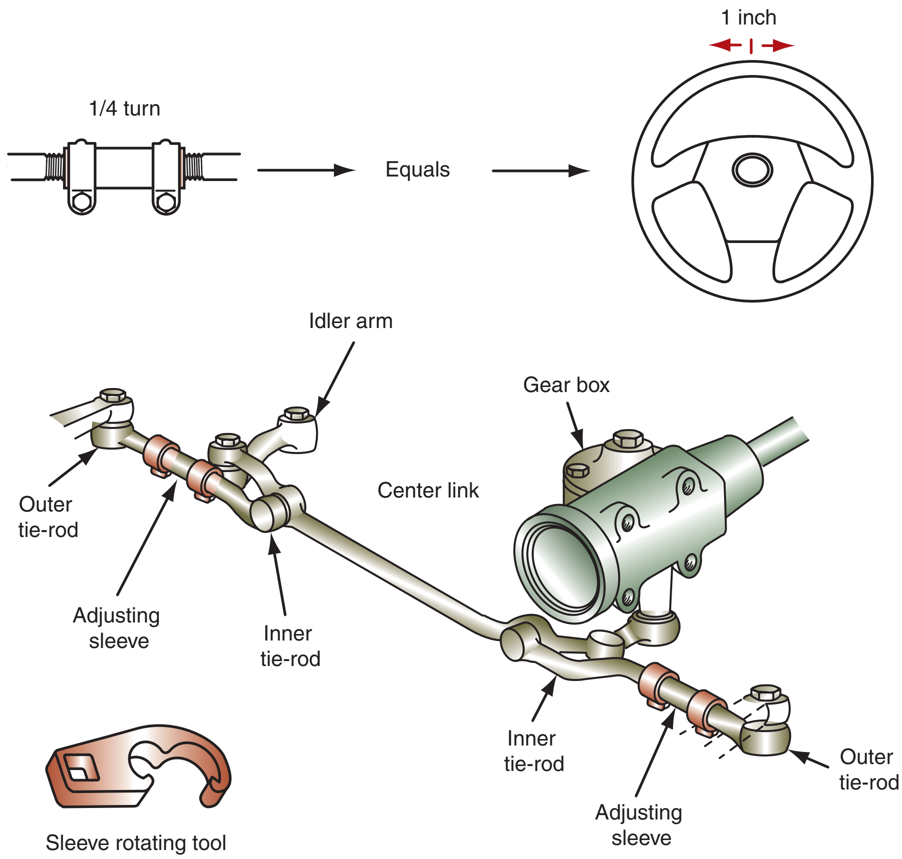

FIGURE 16-44 **Rotating tie-rod sleeves to center steering wheel.**

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When all the front suspension alignment angles are adjusted within the manufacturer's specifications, road-test the vehicle. When the vehicle is driven on a relatively smooth, straight road, there should be directional stability with no drift to the right or left, and the steering wheel must be centered.

Causes of Improper Rear Wheel Alignment

The following suspension or chassis defects will cause incorrect rear wheel alignment:

1. Collision damage that results in a bent frame or distorted unitized body
2. A leaf-spring eye that is unwrapped or spread open
3. Leaf-spring shackles that are broken, bent, or worn
4. Broken leaf springs or leaf-spring center bolts
5. Worn rear upper or lower control arm bushings
6. Worn trailing arm bushings or dislocated trailing arm brackets
7. Bent components such as radius rods, control arms, struts, and rear axles

CAUTION:
Always follow the vehicle manufacturer's recommended rear suspension adjustment procedure in the service manual to avoid improper alignment angles and reduced steering control.

Rear Suspension Adjustments

Rear Wheel Camber Adjustment

Improper **rear wheel camber** causes excessive wear on the edges of the rear tire treads. Cornering stability may be affected by improper rear wheel camber, especially while cornering at high speeds. Improper rear wheel camber on a front-wheel-drive vehicle may change the understeer or oversteer characteristics of the vehicle. Since a tilted wheel rolls in the direction of the tilt, rear wheel camber may cause steering pull. For example, excessive positive camber on the right rear wheel causes the rear suspension to drift to the right and steering to pull to the left.

Rear wheel camber is the tilt of a line through the center of a rear tire and wheel in relation to the true vertical centerline of the tire and wheel.

Rear suspension adjustments vary depending on the type of suspension system. Some manufacturers of wheel alignment equipment and tools provide detailed diagrams for front and rear wheel alignment adjustments on all makes of domestic and imported vehicles. Our objective is to show a few of the common methods of adjusting rear wheel alignment angles on various types of rear suspension systems.

On some semi-independent rear suspension systems, camber and toe are adjusted by inserting different sizes of shims between the rear spindle and the spindle mounting surface. These shims are retained by the spindle mounting bolts. The shim thickness is changed between the top or bottom of the spindle to adjust camber (Figure 16-45).

Many rear camber shims are now circular and are available in a wide variety of config urations to fit various rear wheels. Some computer wheel aligners indicate the thickness of shim required and the proper shim position. These same shims also adjust rear wheel toe (Figure 16-46).

SPECIAL TOOLS
Rear suspension camber tool

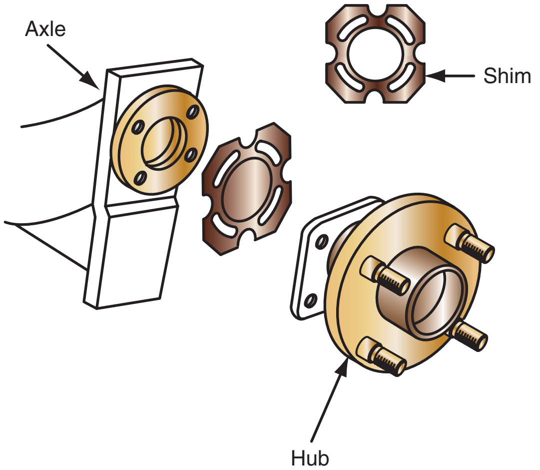


FIGURE 16-45 **Shim adjustment for rear wheel camber, semi-independent rear suspension system.**

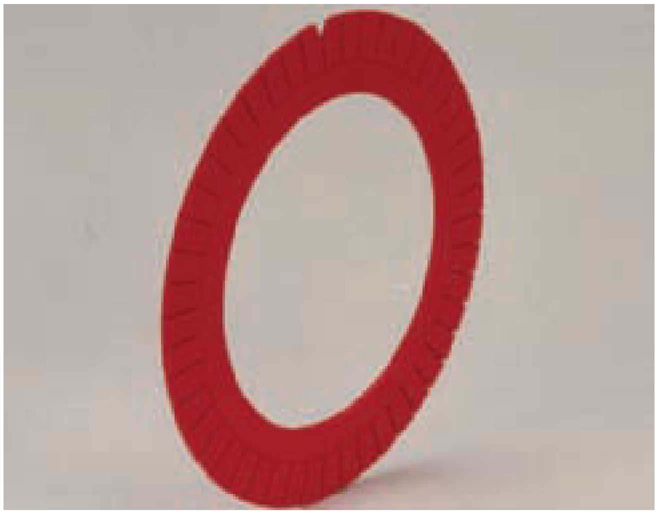


FIGURE 16-46 **Circular shim for rear wheel camber and toe adjustment.**

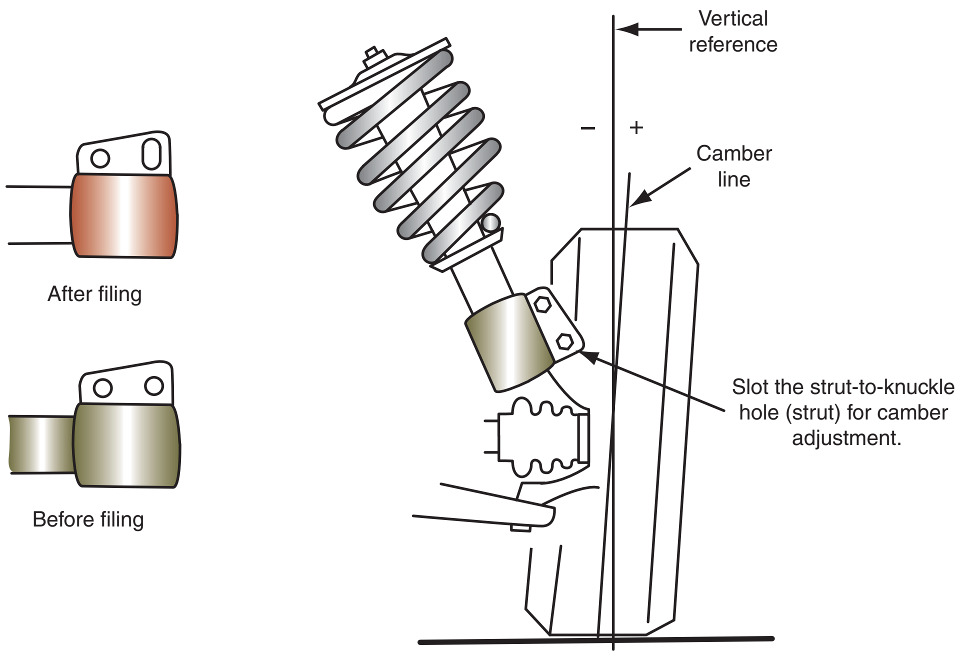


FIGURE 16-47 **Elongating the lower strut bolt hole provides camber adjustment.**

On some transverse leaf rear suspension systems such as those on a later model Oldsmobile Cutlass Supreme, the spindle must be removed from the strut, and the lower strut bolt hole elongated to allow a camber adjustment (Figure 16-47). Once this bolt hole is elongated, assemble the knuckle and strut and leave the retaining bolts loose. The top of the tire and the spindle may be moved outward or inward to adjust camber. After the camber is adjusted to specifications, the strut-to-knuckle nuts must be tightened to the specified torque.

On some independent rear suspension systems with a lower control arm and ball joint, the strut-to-knuckle bolts are loosened and a special camber tool must be installed on the lower strut-to-knuckle bolt and the rear side of the strut (Figure 16-48). Rotate the adjusting bolt in the back of the tool to adjust the camber; then tighten the strut-to-knuckle nuts to the specified torque.

On other rear suspension systems, a camber adjustment wedge may be installed between the top of the knuckle and the strut to adjust camber (Figure 16-49). The nuts on the

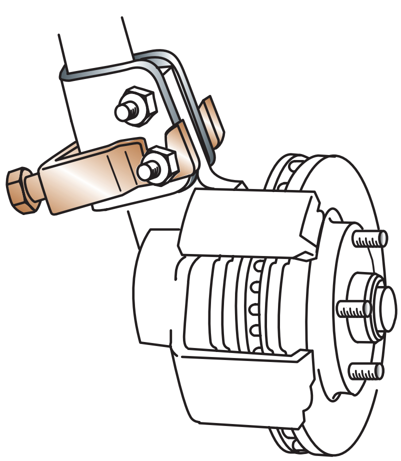


FIGURE 16-48 **Camber adjustment with special tool inserted on rear lower strut-to-knuckle bolt.**

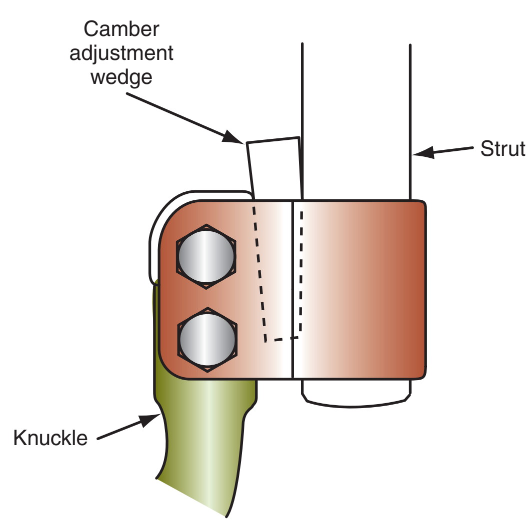


FIGURE 16-49 **Camber adjusting wedge installed between the top of the rear knuckle and strut.**

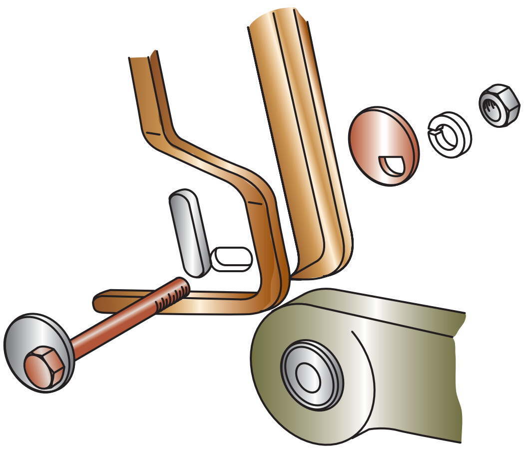


FIGURE 16-50 **Rear wheel camber adjusting kit.**

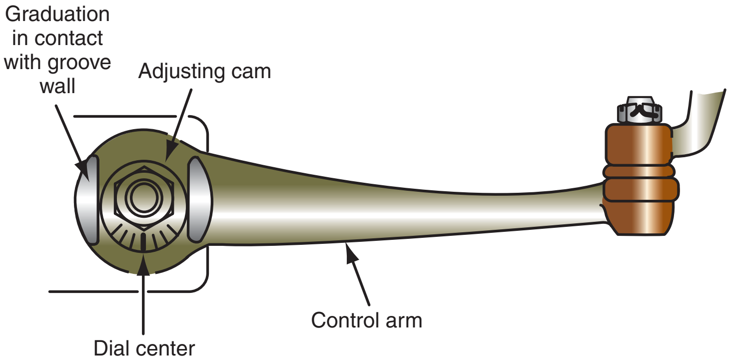


FIGURE 16-51 **Graduated cam for rear camber adjustment, double wishbone suspension.**

strut-to-knuckle bolts must be loosened prior to wedge installation, and these nuts must be tightened to the specified torque after the camber is adjusted to specifications. Aftermarket adjustment cam kits are available to adjust the rear wheel camber on many cars (Figure 16-50). On some double-wishbone rear suspension systems, graduated cams on the inner ends of the lower control arms provide camber adjustment (Figure 16-51). Improper rear wheel camber may be caused by sagged rear springs on some cars or station wagons (Figure 16-52). If the improper rear wheel camber is caused by sagged rear springs, the springs should be replaced and the camber adjusted to specifications.

Rear wheel toe is the distance between the front edges of the rear tires in relation to the distance between the rear edges of the rear tires.

Rear Wheel Toe Adjustment

Improper **rear wheel toe** moves the thrust line away from the geometric centerline, which causes steering pull and feathered tire tread wear. If the left rear wheel has excessive **toe-out**, the **thrust line** is moved to the left of the geometric centerline. Excessive toe-in on the left rear wheel moves the thrust line to the right of the geometric centerline. When toe-in or toe-out is excessive on the right rear wheel, it has the opposite effect on the thrust line compared to the left rear wheel. When the thrust line is moved to the left of the geometric centerline, the steering pulls to the right, whereas a thrust line positioned to the right of the **geometric centerline** results in steering pull to the left. Photo sequence 29 shows rear wheel alignment adjustment procedures.

The **thrust line** is a line at 90° to the rear axle and projecting forward.

Geometric centerline is the true centerline between the front and rear axles.

Improper rear wheel toe adjustment on a non-driving rear axle causes diagonal wipe tire tread wear (Figure 16-53). The toe may be adjusted on many rear suspension systems used on front-wheel-drive cars by changing the tapered shim thickness between the front and rear

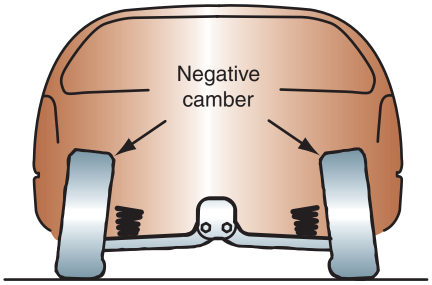


FIGURE 16-52 **Improper rear wheel camber may be caused by sagged rear springs on independent rear suspension systems.**

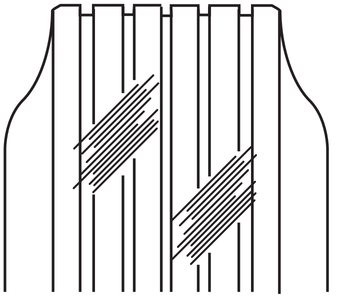


FIGURE 16-53 **Diagonal wipe tire tread wear caused by improper rear wheel toe on a front wheel drive vehicle.**

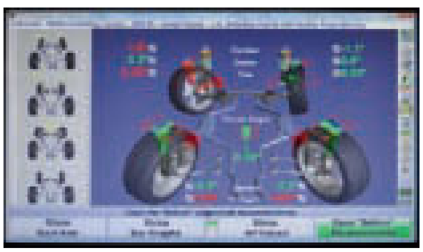
PHOTO SEQUENCE 29

Typical Procedure for Adjusting Rear Wheel Camber and Toe

P29-1 **Be sure the vehicle is properly positioned on an alignment ramp.**

P29-2 **Perform a prealignment inspection.**

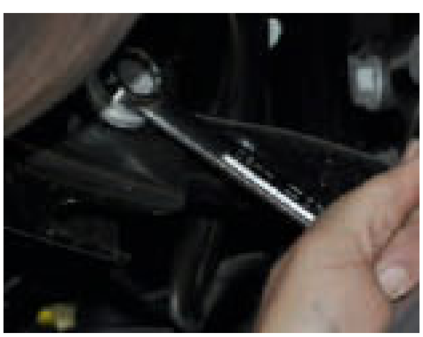
P29-3 **Be sure the wheel aligner wheel sensors are properly connected to the vehicle.**



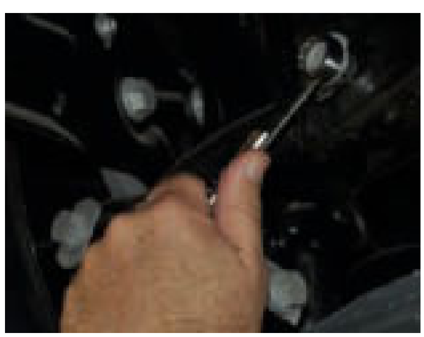
P29-4 **Obtain the front and rear alignment angles using the procedures recommended by the equipment manufacturer. Display the front and rear wheel alignment angles on the aligner monitor.**

P29-5 **Adjust the camber on the right rear wheel by loosening the cam bolt lock nut on the inner end of the right rear lower control arm and turning the eccentric cam until the camber setting is within specifications. Maintain the cam setting and tighten the lock nut to the specified torque.**

P29-6 **Adjust the camber on the left rear wheel by loosening the cam bolt lock nut on the inner end of the right rear lower control arm and turning the eccentric cam until the camber setting is within specifications. Maintain the cam setting and tighten the lock nut to the specified torque.**



P29-7 **Loosen the cam bolt nut on the inner end of the left rear toe link, and rotate the cam bolt to the required toe specification. Maintain the cam bolt position, and tighten the cam bolt nut to the specified torque.**



P29-8 **Loosen the cam bolt nut on the inner end of the right rear toe link, and rotate the cam bolt to the required toe specification. Maintain the cam bolt position, and tighten the cam bolt nut to the specified torque.**

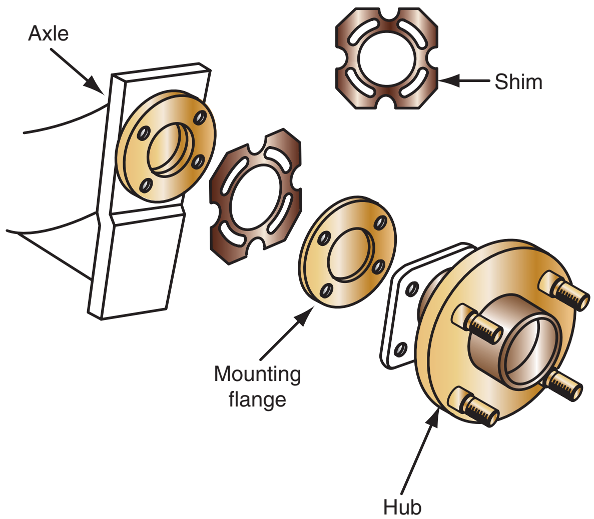


FIGURE 16-54 **Adjusting rear wheel toe by changing shim thickness between rear spindle and mounting flange.**

edges of the rear spindle mounting flange (Figure 16-54). As mentioned previously, these shims are also used to adjust rear wheel camber.

On some transverse leaf rear suspension systems, a special toe adjusting tool is inserted in openings in the jack pad and the rear lower control rod (Figure 16-55). This tool has a turnbuckle in the center of the tool. When the nut on the inner end of the rear lower control rod is loosened, the turnbuckle is rotated to lengthen or shorten the tool and move the rear lower control rod to adjust the rear wheel toe (Figure 16-56). After the toe is adjusted to specification, the nut on the rear lower control rod bolt must be tightened to the specified torque. Photo Sequence 30 illustrates front and rear suspension adjustments.

On some independent rear suspension systems, an eccentric star wheel on the rear lower control rod may be rotated to adjust the rear wheel toe (Figure 16-57).

On some rear suspension systems with a lower control arm and ball joint, the nut on the tie-rod is loosened, and the tie-rod is rotated to adjust the rear wheel toe (Figure 16-58).

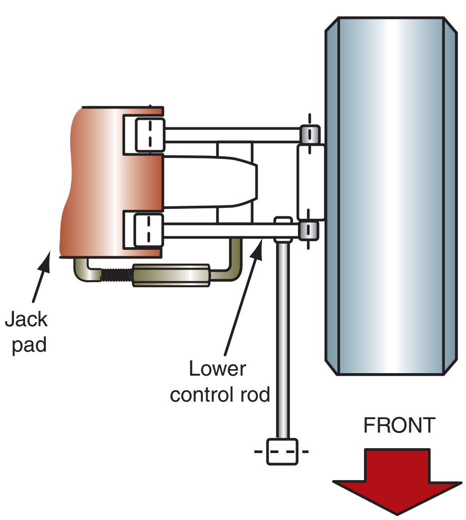


FIGURE 16-55 **Special toe adjusting tool for transverse leaf-spring rear suspension.**

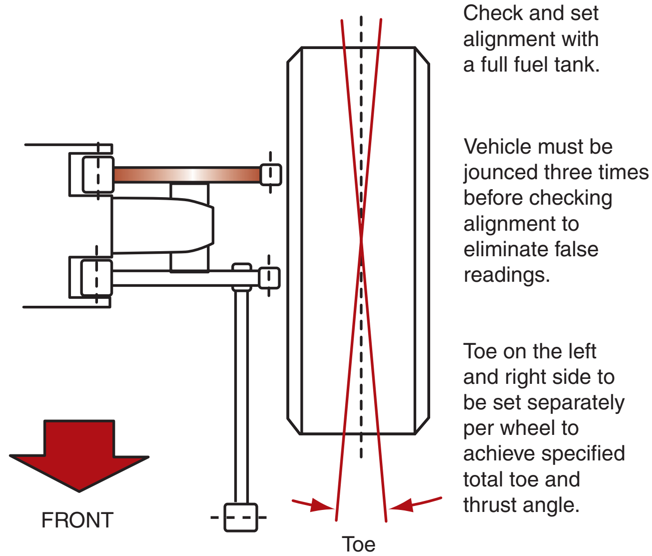


FIGURE 16-56 **Moving lower rear control rod position to adjust rear wheel toe.**

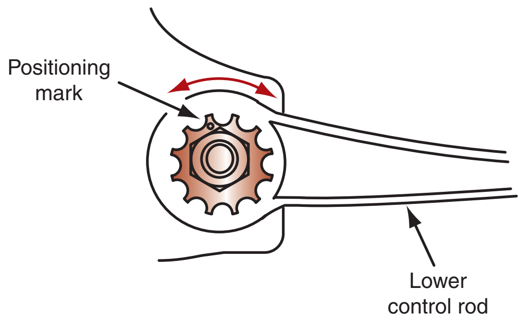


FIGURE 16-57 **Eccentric star wheel on inner end of lower control rod for toe adjustment.**

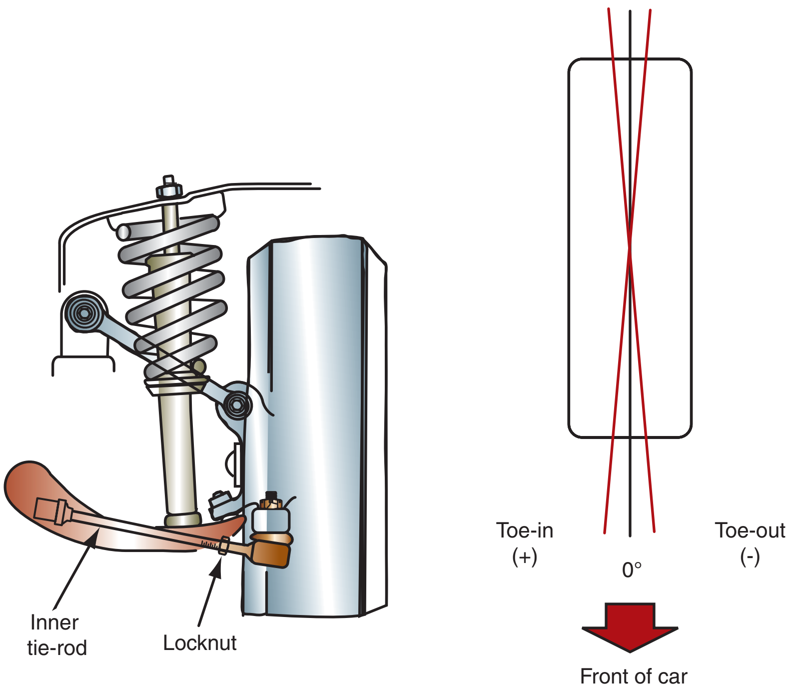


FIGURE 16-58 **Rotating rear tie-rod to change tie-rod length and adjust rear wheel toe.**

After the toe is adjusted to specifications, the tie-rod nut must be tightened to the specified torque.

On some front-wheel-drive cars, the rear wheel toe is adjusted by loosening the toe link bolt and moving the wheel in or out to adjust the toe (Figure 16-59). After the rear wheel toe is properly adjusted, the toe link bolt must be tightened to the specified torque. On other front-wheel-drive cars, the rear wheel toe is adjusted by loosening the nut on the inner adjustment link cam nut (Figure 16-60). The cam bolt is rotated to adjust the rear wheel toe. After the rear wheel toe is properly adjusted, the adjustment link cam nut must be tightened to the specified torque. Photo Sequence 30 illustrates front and rear suspension adjustments.

A variety of aftermarket bushing kits are available to adjust rear wheel toe. Some of these kits also adjust rear wheel comber (Figure 16-61).

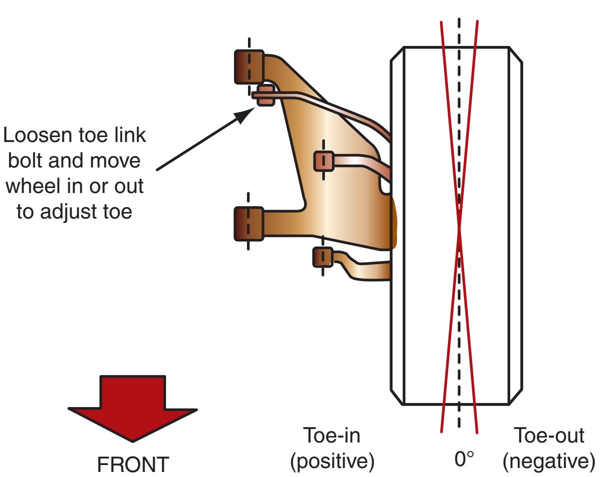


FIGURE 16-59 **Loosening toe link bolt to adjust rear wheel toe.**

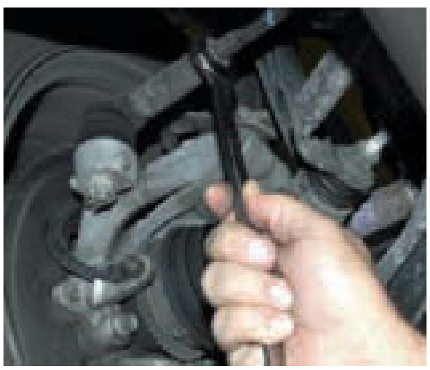
PHOTO SEQUENCE 30

Typical Procedure for Performing Front and Rear Suspension Alignment Adjustments

P30-1 **Position vehicle properly on alignment rack with front wheels centered on turntables and rear wheels on slip plates.**

P30-2 **After prealignment inspection and front and rear ride height measurement, measure front and rear suspension angles with computer wheel aligner.**

P30-3 **Drill spot welds to remove alignment plate on top of the strut tower. After strut upper mount retaining nuts and alignment plate are removed, shift the strut inward or outward to adjust front wheel camber. Shift the upper strut mount forward or rearward to adjust front wheel caster.**

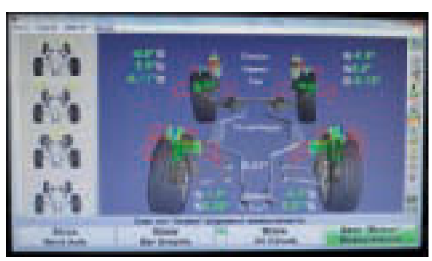


P30-4 **Loosen the locknuts and adjust the tie-rod length to adjust front wheel toe.**

P30-5 **Recheck front suspension alignment readings on the monitor screen.**

P30-6 **Adjust the left rear wheel camber and toe by rotating the cam bolt on the inner end of the lower control arm. If the rear wheel camber and toe have not been adjusted previously, a rear camber adjusting kit may have to be installed in the inner end of the lower control arm.**

P30-7 **Adjust the right rear wheel camber and toe by rotating the cam bolt on the inner end of the lower control arm. If the rear wheel camber and toe have not been adjusted previously, a rear camber adjusting kit may have to be installed in the inner end of the lower control arm.**



P30-8 **Recheck all front and rear alignment readings on the monitor screen. Be sure all readings are within specifications, including the thrust angle.**

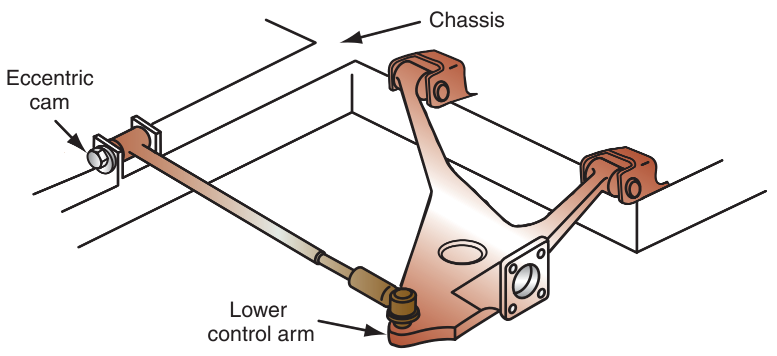


FIGURE 16-60 **Cam bolt for rear wheel toe adjustment.**

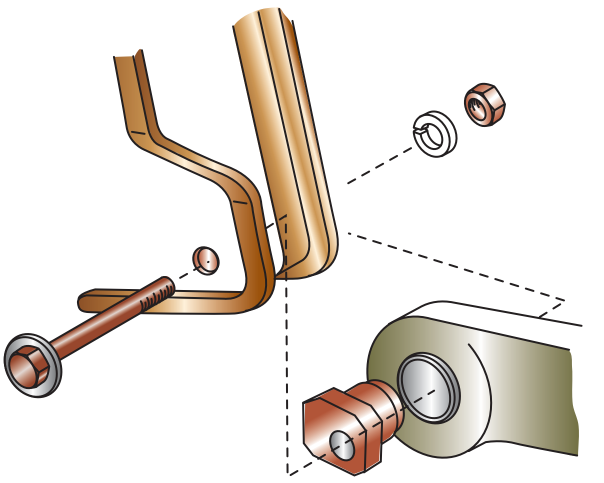


FIGURE 16-61 **Aftermarket bushing kit to adjust rear wheel toe and camber.**

SPECIAL TOOLS
Track gauge

Rear wheel tracking refers to the position of the rear wheels in relation to the front wheels. When all four wheels are parallel to the geometric centerline and the thrust line is positioned on the geometric centerline, the rear wheels track directly behind the front wheels.

Rear Wheel Tracking Measurementwith a Track Gauge

Prior to the introduction of computer alignment systems, wheel alignment equipment performed a two-wheel alignment on the front wheels, and a track gauge was used to measure **rear wheel tracking.** A **track gauge** is connected between the front and rear wheels to determine the rear wheel tracking or thrust line. When all four wheels are parallel to the geometric centerline of the vehicle, the thrust line is positioned at the geometric centerline. Under this condition, the rear wheels track directly behind the front wheels (Figure 16-62).

If the left front of the vehicle is involved in a severe collision, the left front wheel may be driven rearward to a setback condition, and the rear wheels may be moved straight sideways. Under this condition, the rear wheels no longer track directly behind the front wheels (Figure 16-63). The term sideset is applied to the condition where the rear axle is moved straight sideways.

A track gauge is a straight metal bar graduated in inches or millimeters. The scale on the outside edge of the track bar is similar to a tape measure. Three straight metal pointers are mounted in brackets on the track gauge. These pointers are also graduated much like a tape measure. When the wing nuts in the brackets are loosened, the brackets may be moved lengthwise on the track bar. The metal pointers may be adjusted inward or outward in the brackets.

To inspect rear wheel tracking, one of the track gauge pointers is positioned against the rear outside edge of the front wheel rim at spindle height. The other two pointers are positioned on the outside edges of the rear wheel rim at spindle height. The track gauge must be kept parallel to the side of the vehicle (Figure 16-64).

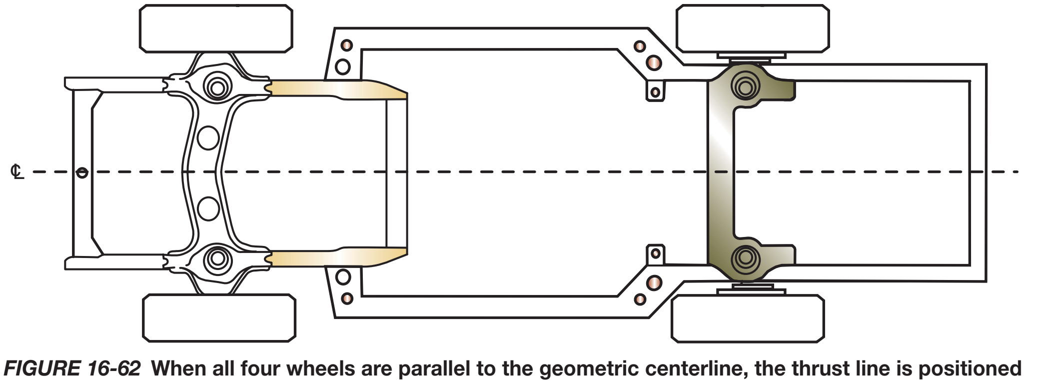


FIGURE 16-62 **When all four wheels are parallel to the geometric centerline, the thrust line is positioned at the geometric centerline and the rear wheels track directly behind the front wheels.**

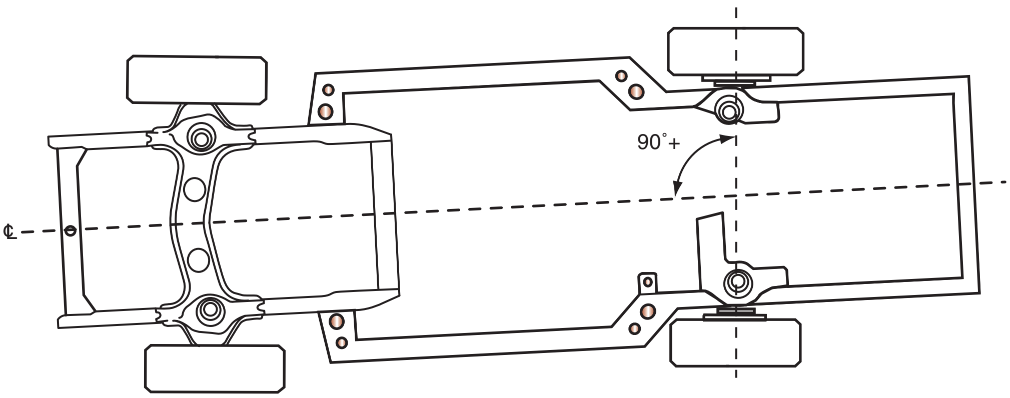


FIGURE 16-63 **Collision damage causes front wheel setback and improper rear wheel tracking with rear wheel offset.**

FIGURE 16-64 **Track bar positioned to measure rear wheel tracking.**

Rear Wheel Tracking Measurement Procedure

Follow these steps to measure rear wheel tracking:

1. Lift one side of the front suspension with a floor jack and lower the suspension onto a safety stand. Be sure the tire is lifted off the shop floor.
2. Place a lateral runout gauge against the outside edge of the rim lip and rotate the wheel to check wheel runout. (Refer to Chapter 4 for wheel runout measurement.) Place a chalk mark at the location of the maximum wheel runout. If the wheel runout is excessive, replace the wheel.
3. Rotate the chalk mark to the exact top or bottom of the wheel, and remove the safety stand and floor jack to lower the wheel onto the shop floor.
4. Repeat steps 1, 2, and 3 at the other three wheels.
5. Hold the single pointer on the track gauge so it contacts the rear edge of the front rim.
6. Adjust the other two pointers so they contact the outer edges of the rear wheel rim.
7. Adjust the pointers on the rear wheel so the track gauge is parallel to the side of the vehicle. Be sure all three pointers are clamped securely.
8. Move the track gauge to the opposite side of the vehicle and position the pointers in the same location on these wheels. If the vehicle has proper tracking, all three pointers

on the track gauge will contact the front and rear rims at exactly the same location on both sides of the vehicle, and the track gauge will be parallel to the sides of the vehicle.

Examples of Improper Rear Wheel Tracking Measured with a Track Gauge

Rear axle offset occurs when the rear axle is turned so one rear wheel is moved rearward and the opposite rear wheel is moved forward.

Rear Axle Offset. When the track gauge is positioned on the left side of the vehicle, the rear pointer on the rear wheel must be moved farther inward compared with the pointer at the front edge of the rear rim. On the right side of the vehicle, the front pointer is positioned forward and ahead of the rim edge when the two pointers are positioned on the edges of the rear rim. This indicates the wheelbase is less between the wheels on the right side of the vehicle compared with the left side. The front pointer on the rear rim is some distance from the rim face (Figure 16-65). These pointer positions indicate the right rear wheel has moved forward and the left rear wheel has moved rearward. This **rear axle offset** condition moves the thrust line to the left of the geometric centerline.

Wheel Setback. If a vehicle has been subjected to a severe right front sideways impact, the left front wheel may be driven outward and rearward. The track gauge and pointers are positioned on the right side of the vehicle and then moved to the left side. The front pointer is positio ned ahead of the rim edge on the left side, and the track gauge is not parallel to the side of the vehicle (Figure 16-66).

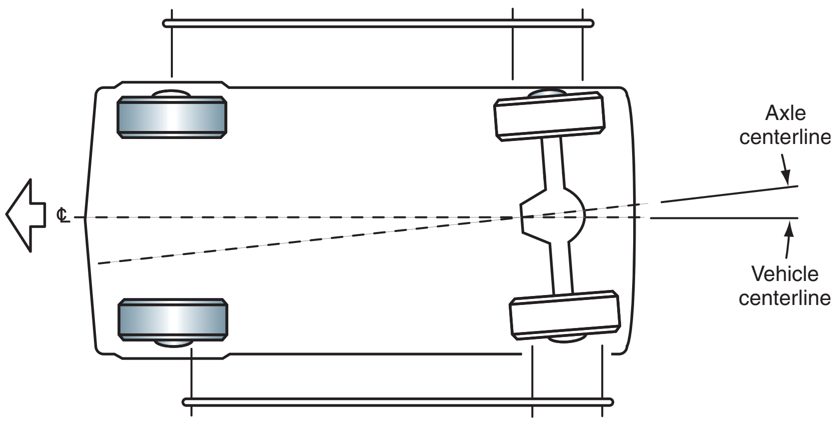


FIGURE 16-65 **Track bar measurement of an offset rear axle.**

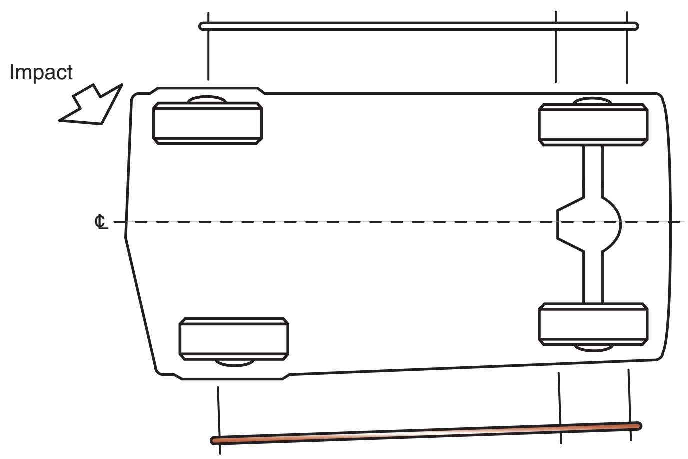


FIGURE 16-66 **Track bar measurement of a left front wheel that is moved rearward to asetback position.**

The track gauge must be moved inward on the front pointer to position the bar parallel to the side of the vehicle. When this adjustment is made, the distance on the front pointer is less on the left side of the vehicle compared with the distance on the right side of the vehicle. These track gauge measurements indicate the left front wheel is moved rearward to a setback position as well as being outward.

Diamond-Shaped Frame Condition. When a vehicle experiences severe collision damage on the left front, the entire left side of the vehicle may be driven rearward in relation to the right side of the chassis. Under this condition, the left front wheel is moved to a setback condition, and the rear axle is offset, which moves the thrust line to the left of the geometric centerline. This particular type of damage is most likely to occur on a rear-wheel-drive vehicle with a frame and a one-piece rear axle.

Since the entire left side of the vehicle is driven rearward, the wheelbase is the same on both sides of the vehicle. Therefore, the track gauge pointers indicate the wheelbase is the same between the front and rear wheels on both sides of the vehicle. However, the two rear track gauge pointers must be adjusted to different lengths to contact the rear rim edges. On the left side of the vehicle, the rear track gauge pointer is some distance from the rear rim edge if these two pointers are set at the same measurement (Figure 16-67).

When the track gauge is positioned on the right side of the vehicle, there is some distance between the front pointer and the edge of the rear rim if both rear pointers are set at the same distance.

Measuring vehicle tracking with a track gauge is a two-person operation and requires a considerable amount of time to perform the wheel runout and track bar measurements. The track gauge also lacks precision accuracy. Computer alignment systems perform the same checks by measuring the thrust line angle, setback, and all the other front and rear suspension alignment angles with speed and accuracy.

CUSTOMER CARE: Those of us involved in the automotive service industry are like everyone else: we do make mistakes. If you make a mistake that results in a customer complaint, always be willing to admit your mistake and correct it. Do not try to cover up the mistake or blame someone else. Customers are usually willing to live with an occasional mistake that is corrected quickly and efficiently.

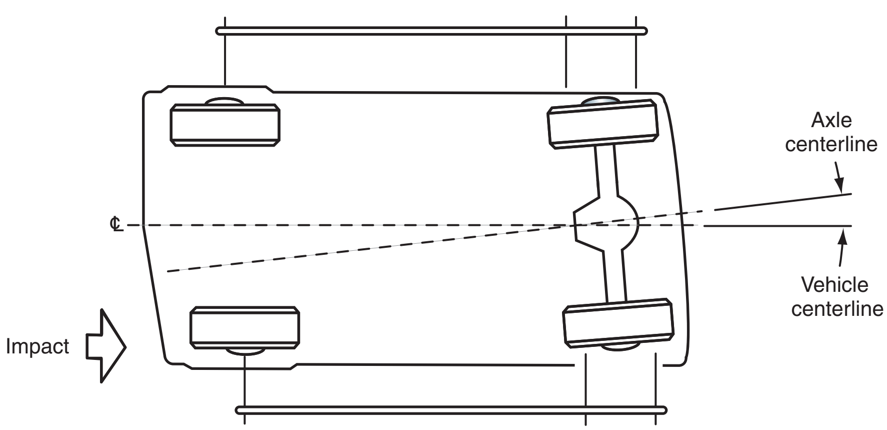


FIGURE 16-67 **A severe left front collision impact moves the entire left side of the vehicle rearward resulting in front wheel setback and rear axle offset, which provides a diamond-shaped chassis.**

TABLE 16-1 **STEERING AND WHEEL ALIGNMENT DIAGNOSIS**

Problem	Symptoms	Possible Causes
Tire tread wear, inside edge	Steering pull, premature tire replacement	Excessive negative camber
Tire tread wear, outside edge	Steering pull, premature tire replacement	Excessive positive camber
Tire tread wear, feathered	Premature tire replacement	Improper toe setting
Tire tread wear, cupped	Wheel vibration	Improper wheel balance
Steering wander	Reduced directional stability	Reduced positive caster or negative caster
Steering pull	Steering pull to the right when driving straight ahead	Reduced positive caster, right-front wheel Excessive positive camber, right-front wheel Excessive toe-out, left-rear wheel
Steering pull	Steering pull to the left when driving straight ahead	Reduced positive caster, right-front wheel Excessive positive camber, right-front wheel Excessive toe-out, right-rear wheel
Steering wheel return	Excessive steering wheel returning force after a turn	Excessive positive caster on front wheels
Steering wheel return	Steering wheel does not return properly after a turn	Binding column or linkage Reduced positive caster on front wheels
Harsh riding	Reduced ride quality when driving on road irregularities	Worn shock absorbers or struts Excessive positive caster, front wheels. Reduced ride height

CASE STUDY

A customer complained that the left rear tire on his Cutlass Calais had suffered severe tread wear in the last 2,000 miles. The technician examined this tire and found the customer was not exaggerating. All the tread wear indicators were showing and the other tires showed very little wear. The customer indicated that the left rear tire tread looked like the tread on the other tires 2,000 miles previously. While checking the tread wear on the left rear tire, the technician noticed the car had been newly painted. Further discussion with the customer revealed the car had been recently purchased, and there was no warranty on the vehicle. During a road test, the technician found that the steering pulled to the left while driving straight ahead. The technician suggested a thorough prealignment inspection and complete four-wheel alignment with a computer alignment system.

During the prealignment inspection, all the steering and suspension components except the left rear tire appeared to be in normal condition. However, the technician noticed the left rear quarter panel and other body components had been replaced. Apparently the car had suffered severe collision damage in this area.

The four-wheel alignment results were satisfactory except the left rear wheel, which had a 5° toe-in and a thrust angle of 8°. This severe rear toe-in condition had moved the thrust line to the right of the geometric centerline. When the technician referred to the manufacturer's service manual, this information stated the rear wheel toe is not adjustable, and if the rear wheel camber and toe are not within specifications, the rear underbody and suspension should be inspected for damage. The technician located the underbody dimension specifications in the service manual (Figures 16-68 and 16-69).

The technician began checking the rear suspension underbody measurements with a tram gauge. When

dimension M was measured between the center of the bolt heads in the trailing arm brackets, this measurement was 1 in. (25.4 mm) less than specified. This measurement indicated the left rear subframe had been forced inward toward the center of the vehicle, which resulted in the improper toe and thrust angle. Further inspection of the rear axle channel with a long straightedge indicated this channel was bent rearward in the center. The car was sent to the body shop to pull the rear subframe and unitized body back to the original position and provide the specified distance between the center of bolt heads on the trailing arms. Since the rear axle channel is a critical component in providing rear suspension ride quality and alignment, the customer was advised this component should be replaced. A new rear tire was also installed.

When the rear suspension was reassembled, all the alignment angles were rechecked and the rear wheel toe and thrust line were within specifications. During a road test, there was no evidence of steering pull or any other steering problems.

From this experience, the technician learned the importance of four wheel alignment. The technician also discovered that accurate underbody measurement specifications are absolutely essential.

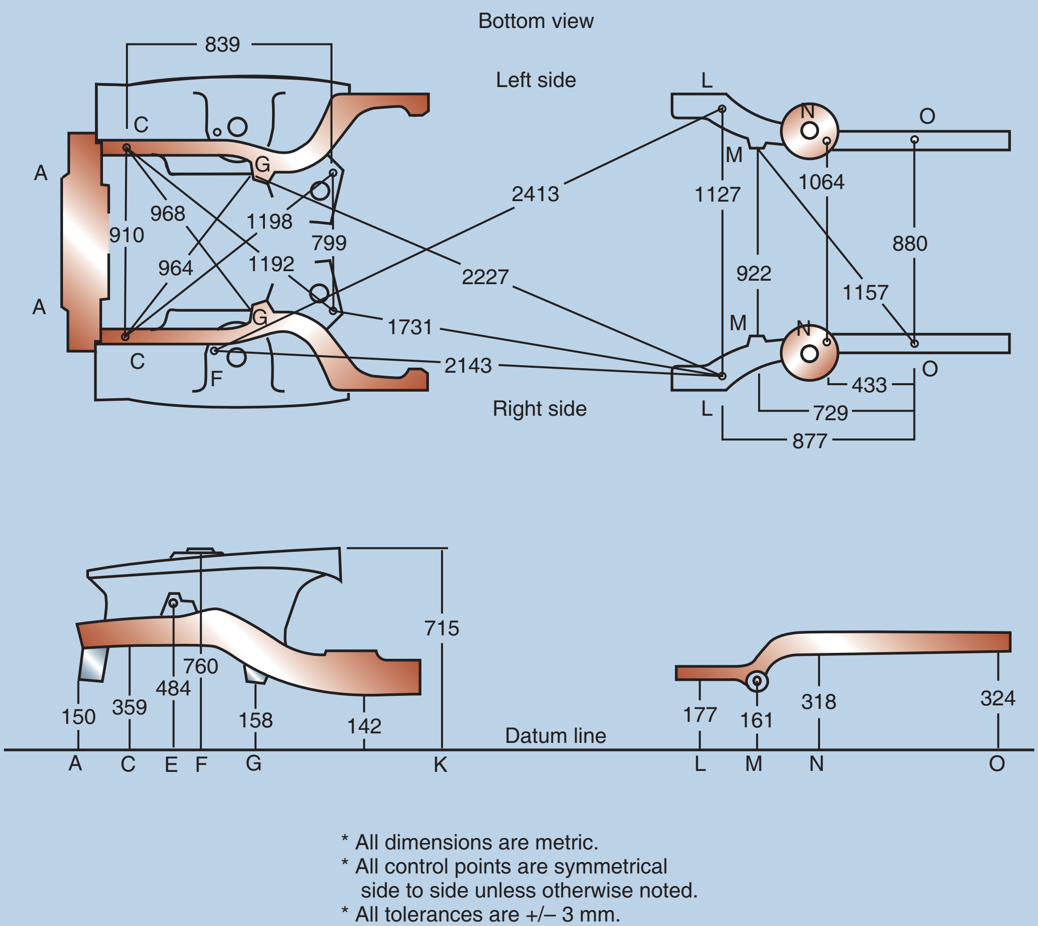


FIGURE 16-68 **Underbody measurement specifications and locations.**

REF	HORIZONTAL	VERTICAL	LOCATION
A	Leading edge of 24 mm gauge hole	Lower surface at gauge hole to datum line	Front end lower tie bar
B	Center of 16 mm gauge hole	None	Front end upper tie bar
C	Leading edge of 20 mm gauge hole	Lower surface at gauge hole to datum line	Motor compartment side rail, forward of transaxle anchor support plate on left side rail, and at rear of engine mounting support on right side rail. For access on right side with air conditioning, remove air compressor.
D	Center of 16 mm gauge hole	None	Front upper surface of motor compartment side rail
E	Center of lower attaching hole in transaxle support anchor plate	Datum line to horizontal centerline of transaxle support anchor plate lower attaching hole	Transaxle support anchor plate on left side rail
F	Center of shock tower strut front attaching hole	Upper surface at shock tower strut front attaching hole	Shock tower
G	Leading edge of oblong master gauge hole	Datum line to horizontal leading edge of oblong master gauge hole	Front suspension lower control arm mount support
H	Center of 16 mm gauge hole	None	Gage hole in upper surface of motor compartment side rail
I	Center of 19 mm gauge hole	Datum line to lower surface at gauge hole	Outboard 19 mm gauge hole in front suspension control arm mounting reinforcement support
J	Center of hood hinge pivot pin head	None	Hood hinge
K	Center of front upper hinge pin hole	Upper surface at hinge pin hole	Front upper door hinge, body side
L	Leading edge of 22 mm gauge hole	Lower surface at leading edge of gauge hole to datum line	Compartment pan longitudinal rail, forward of rear suspension spring seat support
M	Center of attaching bolt head	Datum line to horizontal centerline of attaching bolt head of rear suspension control arm support.	Rear suspension control arm support forward of rear suspension spring seat support
N	Center of 16 mm gauge hole	Datum line to lower surface at gauge hole	Outboard gage hole at rear suspension spring seat support
O	Leading edge of 21 mm gauge hole	Lower surface at gauge hole to datum line	Compartment pan longitudinal rail

FIGURE 16-69 **Explanation of underbody horizontal and vertical measurement locations.**

TERMS TO KNOW

Camber adjustment
Caster adjustment
Eccentric cams
Geometric centerline
Rear axle offset
Rear wheel camber
Rear wheel toe
Rear wheel tracking
Setback
Steering axis inclination (SAI)
Thrust line
Toe-in
Toe-out
Total toe
Track gauge

ASE-Style Review Questions

1. While discussing camber adjustments on a MacPherson strut front suspension system:

   Technician A says an eccentric cam on the strut-to-steering-knuckle bolt may be used to adjust camber.

   Technician B says an eccentric on the lower ball joint stud may be used to adjust camber.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

2. While discussing camber adjustment on a short-and-long arm front suspension system with adjusting shims positioned between the upper control arm mounting shaft and the outside of the frame:

   Technician A says adding equal shim thickness on both mounting bolts increases negative camber.

   Technician B says adding more shim thickness on the front bolt decreases positive camber.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. While diagnosing and adjusting front wheel camber:

   A. Front wheel camber is measured with the front wheels turned 20°.
   B. The steering pulls to the side with the least amount of positive camber.
   C. The right front wheel may have more positive camber to compensate for road crown.
   D. The upper strut mount may be moved inward or outward to adjust camber.

4. When diagnosing and adjusting front wheel caster:

   A. On some suspensions, the radius rod should be shortened to decrease positive caster.
   B. On some twin I-beam suspensions, the I beams may be bent to adjust caster.
   C. On some double-wishbone suspensions, a graduated cam on the pivot adjuster is rotated to adjust caster.
   D. The steering pulls to the side of the suspension that has the most positive caster.

5. The camber adjustment is within specifications, but the SAI angle is more than specified on the left side of a MacPherson strut front suspension.

   Technician A says the camber adjustment bolt may be adjusted to correct the problem.

   Technician B says the left front wheel may have a setback condition.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

6. Unequal SAI angles on the left and right sides of the front suspension may cause:

   A. Tread wear on the front tires.
   B. Brake pull during sudden stops.
   C. Bump steer on a rough road.
   D. Steering wander while driving straight ahead.

7. On many front suspension systems, the maximum variation between the left and right SAI is:

   A. 0.75° C. 1.5°
   B. 1° D. 2.5°

8. All of these statements about adjusting front wheel toe are true EXCEPT:

   A. If the positive caster is increased on the right front wheel, this wheel moves toward a toe-out position.
   B. The tie-rod sleeves may be heated with an acetylene torch to loosen them.
   C. The opening in the sleeve clamp must be positioned away from the slots in the tie-rod sleeve.
   D. The front wheel toe should be measured with the front wheels straight ahead.

9. A rear independent suspension system has a tie-rod connected from the steering knuckle to the lower control arm.

   Technician A says if the tie-rod is lengthened, the rear wheel is moved toward a toe-out position.

   Technician B says if the tie-rod is shortened, the positive camber is increased on the rear wheel.

   Who is correct?

   A. A only C. Both A and B
   B. B only D. Neither A nor B

10. While discussing a vehicle on which the front suspension alignment angles are within manufacturer's specifications, but the thrust line is 7° to the right of the vehicle centerline:

    Technician A says this problem may be caused by excessive toe-out on the right rear wheel.

    Technician B says this vehicle will tend to steer to the left when driven straight ahead.

    Who is correct?

    A. A only C. Both A and B
    B. B only D. Neither A nor B

ASE Challenge Questions

1. A car with a MacPherson strut front suspension has 1.5° positive camber on the left front wheel and 1.5° negative camber on the right front wheel. The most likely cause of this problem is:
   A. Worn upper strut mounts.
   B. Improperly positioned steering gear.
   C. Engine cradle shifted to the right.
   D. Bent strut rods.

2. A pickup truck with a MacPherson strut front suspension pulls to the left. Preliminary inspection shows that the SAI is correct, but the camber of the right front wheel is –1 1/4°.

   Technician A says a bent spindle could be the cause.

   Technician B says the problem may be a worn-out strut.

   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

3. The nose of a car seems to "push" into the turn when making a right turn.

   Technician A says the probable cause is there is not enough left front wheel toe-out on turns.

   Technician B says the probable cause is too much positive camber on the left rear wheel.

   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

4. "Feathering" type wear of a rear tire is likely caused by:
   A. Improper rear wheel camber alignment.
   B. Improper rear tire inflation.
   C. Improper rear wheel balance.
   D. Improper rear wheel toe alignment.

5. The owner of an older pickup says the truck has begun to "wander and shimmy" in the past few months, especially when the bed of the truck is empty.

   Technician A says the twin I-beam front suspension caster is probably out of spec.

   Technician B says the eyes of the rear leaf springs are probably worn.

   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

Name ________________________________ **Date** ____________________

Center Steering Wheel

Upon completion of this job sheet, you should be able to center a steering wheel.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Task: E-3: Prepare vehicle for wheel alignment on the alignment machine; perform four wheel alignment by checking and adjusting front and rear wheel caster camber; and toe as required; center steering wheel.

Tools and Materials

Tie-rod sleeve adjusting tool

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ________________________

VIN ______________________________ Engine type and size ________________________

Procedure

Task Completed

1. List the suspension and steering service procedures that may require steering wheel centering after these procedures are completed.

____

____

____

____

2. The steering wheel is centered properly with the front wheels straight ahead in the shop, but the steering wheel is not centered when driving the vehicle straight ahead. List the causes of this problem.

____

____

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3. Lift the front end of the vehicle with a hydraulic jack, and position safety stands under the lower control arms. Lower the vehicle onto the safety stands, and place the front wheels in the straight-ahead position.

   Are the lower control arms securely supported on safety stands? ☐ Yes ☐ No

   Are the front wheels straight ahead? ☐ Yes ☐ No

   Instructor check ____

Task Completed

4. Use a piece of chalk to mark each tie-rod sleeve in relation to the tie-rod, and loosen the sleeve clamps.

   Are the tie-rod sleeves marked in relation to the tie-rods? ☐ Yes ☐ No

   Instructor check ______________________________

5. Position the steering wheel spoke in the position it was in while driving straight ahead during the road test. Turn the steering wheel to the centered position and note the direction of the front wheels.

   Direction the front wheels are turned with the steering wheel centered:
   right ______________ left ______________

6. If the steering wheel spoke is low on the left side while driving the vehicle straight ahead, use a tie-rod sleeve rotating tool to shorten the left tie-rod and lengthen the right tie-rod. A one-quarter turn on a tie-rod sleeve moves the steering wheel position approximately one inch. Turn the tie-rod sleeves the proper amount to bring the steering wheel to the centered position. For example, if the steering wheel spoke is two inches off-center, turn each tie-rod sleeve one-half turn.

   Left tie-rod sleeve: lengthened ______________ shortened ______________

   Right tie-rod sleeve: lengthened ______________ shortened ______________

   Amount of left tie-rod sleeve rotation ______________________________

   Amount of right tie-rod sleeve rotation ______________________________

   Is the steering wheel centered with front wheel straight ahead? ☐ Yes ☐ No

   Instructor check ______________________________

☐

7. If the steering wheel spoke is low on the right side while driving the vehicle straight ahead, lengthen the left tie-rod and shorten the right tie-rod.

8. Mark each tie-rod sleeve in its new position in relation to the tie-rod. Be sure the sleeve clamp openings are positioned properly, as indicated in this chapter. Tighten the clamp bolts to the specified torque.

   Are the tie-rod sleeves marked in relation to tie-rods? ☐ Yes ☐ No

   Are the tie-rod sleeve clamps properly installed? ☐ Yes ☐ No

   Tie-rod sleeve bolt specified torque ______________________________

   Tie-rod sleeve bolt actual torque ______________________________

   Instructor check ______________________________

9. Lift the front chassis with a floor jack, and remove the safety stands. Lower the vehicle onto the shop floor, and check the steering wheel position during a road test.

   Steering wheel position while driving straight ahead during a road test:
   ☐ Satisfactory ☐ Unsatisfactory

Instructor's Response ______________________________

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Name ______________________________ Date ____________________

ADJUST FRONT WHEEL ALIGNMENT ANGLES

Upon completion of this job sheet, you should be able to adjust front wheel alignment angles.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Tasks:

E-2. Perform prealignment inspection and measure vehicle ride height; perform necessary action.

E-3. Prepare vehicle for wheel alignment on the alignment machine; perform four-wheel alignment by checking and adjusting front and rear wheel caster, camber, and toe as required; center steering wheel.

E-4. Check toe-out on turns (turning radius); determine necessary action.

E-5. Check steering axis inclination (SAI) and included angle; determine necessary action.

E-7. Check front wheel setback; determine necessary action.

E-8. Check front and/or rear cradle (subframe) alignment; determine necessary action.

Tools and Materials

A vehicle with improperly adjusted front wheel camber, caster, and toe.

Describe the Vehicle Being Worked On:

Year __________ Make ____________________ Model ________________________

VIN ______________________________ Engine type and size ________________________

Procedure

Task Completed

1. Position the vehicle properly on the alignment ramp with the front wheels properly positioned on the turntables and the rear wheels on slip plates.

   Are the front wheels properly positioned on turntables? ☐ Yes ☐ No

   Are the rear wheels properly positioned on slip plates? ☐ Yes ☐ No

   Is the parking brake applied? ☐ Yes ☐ No

   Instructor check ____

2. Perform a prealignment inspection and correct any defective conditions or components found during the inspection. List the defective conditions or components, and explain the reasons for your diagnosis.

   ____

   ____

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Task Completed ________

3. Measure front and rear ride height and correct it if necessary.

Specified front suspension ride height ________________

Actual front suspension ride height ________________

Specified rear suspension ride height ________________

Actual rear suspension ride height ________________

List the necessary repairs to correct the front and rear suspension ride height and explain the reasons for your diagnosis.

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4. Measure and adjust front wheel camber.

Specified front wheel camber ________________

Actual front wheel camber: left ________________ right ________________

Front wheel camber after adjustment: left ________________ right ________________

Camber adjustment method ________________

5. Measure SAI and included angle.

Specified SAI ________________________

Actual SAI: left ________________________ right ________________________

Specified included angle ________________________

Actual included angle: left ____________________ right ____________________

If the SAI and/or included angle are not within specifications, state the necessary repairs and explain the reasons for your diagnosis.

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6. Measure and adjust front wheel caster.

Specified front wheel caster ____________________

Actual front wheel caster: left ________________ right ________________

Front wheel caster after adjustment: left ________________ right ________________

Caster adjustment method ____________________

7. Inspect camber measurements and adjust if necessary.

Camber adjustment: ☐ Satisfactory ☐ Unsatisfactory

Left front camber readjusted to ____________________

Right front camber readjusted to ____________________

8. Measure and adjust front wheel toe.

Task Completed ______

Specified front wheel toe ______

Actual front wheel toe: left ______ right ______

Total toe ______

Front wheel toe after adjustment: left ______ right ______

Total front wheel toe ______

9. Inspect steering wheel centering with front wheels straight ahead and center the wheel if necessary.

Is steering wheel centered? ☐ Yes ☐ No

Instructor check ______

10. Measure turning angle.

Specified turning angle ______

Actual turning angle left front wheel ______

Actual turning angle right front wheel ______

Turning angle correction required: ☐ Yes ☐ No

Left front wheel turned inward 20°, turning angle on right front wheel ______

Right front wheel turned inward 20°, turning angle on left front wheel ______

If the turning angle is not within specifications, state the necessary repairs and explain the reasons for your diagnosis.

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Instructor's Response ______

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Name ______________________ Date ______________

Adjust Rear Wheel Alignment Angles

Upon completion of this job sheet, you should be able to adjust rear wheel alignment angles.

NATEF Correlation

This job sheet is related to NATEF Automotive Suspension and Steering Tasks:

E-2. Perform prealignment inspection and measure vehicle ride height; perform necessary action.

E-3. Prepare vehicle for wheel alignment on the alignment machine; perform four-wheel alignment by checking and adjusting front and rear wheel caster, camber, and toe as required; center steering wheel.

E-6. Check rear wheel thrust angle; determine necessary action.

Tools and Materials

A vehicle with improperly adjusted rear wheel camber and toe.

Describe the Vehicle Being Worked On:

Year ________ Make ______________ Model ________________

VIN ________________ Engine type and size ________________

Procedure

Task Completed

1. Position the vehicle properly on the alignment ramp with the front wheels properly positioned on the turntables and the rear wheels on slip plates.

   Are the front wheels properly positioned on turntables? ☐ Yes ☐ No

   Are the rear wheels properly positioned on slip plates? ☐ Yes ☐ No

   Is the parking brake applied? ☐ Yes ☐ No

   Instructor check ______________________________

2. Perform a prealignment inspection, and correct any defective conditions or components found during the inspection. List the defective conditions or components, and explain the reasons for your diagnosis.

   ____

   ____

   ____

Task Completed ________

3. Measure front and rear ride height and correct if necessary.

Specified front suspension ride height ______________________

Actual front suspension ride height ______________________

Specified rear suspension ride height ______________________

Actual rear suspension ride height ______________________

If the rear ride height is not within specifications, state the necessary repairs and explain the reasons for your diagnosis.

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4. Measure and adjust camber on left rear wheel.

Specified left rear wheel camber ______________________

Actual left rear wheel camber ______________________

Left rear wheel camber after adjustment ______________________

Camber adjustment method ____

5. Measure left rear wheel toe.

Specified left rear wheel toe ______________________

Actual left rear wheel toe ______________________

Left rear wheel toe after adjustment ______________________

Toe adjustment method ____

6. Measure and adjust camber on right rear wheel.

Specified right rear wheel camber ______________________

Actual right rear wheel camber ______________________

Right rear wheel camber after adjustment ______________________

Camber adjustment method ____

7. Measure right rear wheel toe.

Specified right rear wheel toe ______________________

Actual right rear wheel toe ______________________

Right rear wheel toe after adjustment ______________________

Toe adjustment method ____

8. Measure thrust angle.

Specified thrust angle ______________________

Actual thrust angle ______________________

If the thrust angle is not within specifications, state the necessary repairs and explain the reasons for your diagnosis.

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9. Road-test vehicle for satisfactory steering and suspension operation.

Steering directional control: ☐ Satisfactory ☐ Unsatisfactory

Complete steering operation: ☐ Satisfactory ☐ Unsatisfactory

Suspension operation: ☐ Satisfactory ☐ Unsatisfactory

If the steering or suspension operation is unsatisfactory, state the necessary repairs and explain the reasons for your diagnosis.

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Task Completed ☐

Instructor's Response ____
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1. After new tires and new alloy rims are installed on a sports car, the owner complains about steering wander and steering pull in either direction while braking.

   Technician A says there may be brake fluid on the front brake linings.

   Technician B says the replacement rims may have a different offset than the original rims.

   Who is correct?

   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

2. *Technician A* says when a vehicle pulls to one side, the problem will not be caused by the manual steering gear.

   Technician B says when an unbalanced power steering gear valve causes a vehicle to pull to one side, the steering effort will be very light in the direction of the pull and normal or heavier in the opposite direction.

   Who is correct?

   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

3. The outside edge of the left front tire on a rear-wheel-drive car is badly scalloped.

   Technician A says the cause could be worn ball joints.

   Technician B says the cause could be incorrect tire pressure.

   Who is correct?

   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

4. The owner of a large rear-wheel-drive sedan says the front tires squeal loudly during low-speed turns. The most probable cause of this condition is:

   A. Excessive positive camber.
   B. Negative caster adjustment.
   C. Improper steering axis inclination (SAI).
   D. Improper turning angle.

5. A mini-pickup has a severe shudder when the vehicle is started from a stop with a load in the bed.

   Technician A says the problem may be worn spring eyes.

   Technician B says the problem may be axle torque wrap-up.

   Who is correct?

   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

6. A cyclic noise ("moaning," "whining," or "howling") that changes pitch with road speed and is present whenever the vehicle is in motion may be caused by any of the following EXCEPT:

   A. Worn differential gears.
   B. Rear axle bearings.
   C. Incorrect driveshaft runout.
   D. Off-road tire tread pattern.

7. *Technician A* says hard steering may be caused by low hydraulic pressure due to a stuck flow control valve in the pump.

   Technician B says hard steering may be caused by low hydraulic pressure due to a worn steering gear piston ring or housing bore.

   Who is correct?

   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

8. Tires and wheels on a pickup truck were changed from standard 14-inch to standard 15-inch light-truck rims. The first time the brakes were applied, the truck shook and shuddered. When the 15-inch wheels were replaced by the 14-inch wheels, braking was uneventful.

   Technician A says the 15-inch rim is one inch wider, which causes the brakes to grab.

   Technician B says the additional inch diameter increases braking leverage, overloading worn suspension bushings.

   Who is correct?

   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

9. While discussing tire tread wear:

   Technician A says a scalloped pattern of tire wear indicates an out-of-round wheel or tire.

   Technician B says uneven wear on one side of a tire may indicate radial force variation.

   Who is correct?

   A. Technician A C. Both A and B
   B. Technician B D. Neither A nor B

10. A front-wheel-drive car makes chattering noises only during a hard right turn.
    Technician A says the problem is probably caused by an upper spring seat binding.
    Technician B says the problem is probably caused by a defective strut bearing.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

11. A customer says he equipped the rear of his minivan with inflatable air shocks to handle heavier trailer hitch tongue weights, but the van's rear end still drags when he hooks up his ski boat trailer.
    Technician A says the problem is the air shocks are not heavy-duty.
    Technician B says the problem is heavy-duty springs are also needed with the air shocks.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

12. All of the following could cause shock absorber noise EXCEPT:
    A. A bent piston rod.
    B. Worn shock absorbers.
    C. Shock fluid leaks.
    D. Extreme temperatures.

13. When a vehicle pulls to one side, any of the following problems may be the cause EXCEPT:
    A. Worn ball joints.
    B. Reduced curb height.
    C. Bent strut rod.
    D. Improper turning angle.

14. A customer says when he applied the brakes hard on his front-wheel-drive car, "the whole car shook."
    Technician A says the problem could be worn ball joints.
    Technician B says the problem could be worn or loose strut rod bushings.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

15. A customer with a sport utility vehicle says after an off-road outing over the weekend, his vehicle pulls to the left on acceleration. Which of the following could cause this problem?
    A. Broken leaf spring center bolt.
    B. Loose steering unit.
    C. Stuck brake pad.
    D. Stuck in 4WD.

16. While discussing electronic air suspension:
    Technician A says the compressor must be running when a corner of the vehicle is lifted from the ground.
    Technician B says on a car with electronic air suspension, the switch should be in the "on" position.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

17. Front wheel "shimmy"—a side-to-side movement of the front wheels that is felt in the steering wheel—may be caused by any of the following EXCEPT:
    A. Worn tie-rod ends.
    B. Tire/wheel imbalance.
    C. Rack bushings and rack alignment.
    D. Tight sector shaft adjustment.

18. A customer says her front-wheel-drive car is hard to steer because the steering wheel no longer returns to center. After the turn, she has to bring it back to center.
    Technician A says a corroded or stuck strut bearing plate could be the cause of the problem.
    Technician B says a bent tension rod could be the cause of the problem.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

19. While discussing four-wheel steering (4WS):
    Technician A says only a fault in the main steering angle sensor will cause a DTC in the Honda Prelude 4WS main processing unit.
    Technician B says temporary codes in the Honda Prelude 4WS system are stored in memory and recalled each time the ignition key is turned on.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

20. In a hybrid electric vehicle (HEV) the propulsion motor charges the batteries during:
    A. Wide open throttle.
    B. Fast vehicle acceleration.
    C. Idle speed.
    D. Deceleration.

21. While discussing suspension height:
    Technician A says raising the suspension height in the rear of a vehicle will affect the front suspension geometry.
    Technician B says raising the suspension height in the rear of a vehicle could lead to premature rear spring failure.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

22. A vehicle with recirculating ball steering has excessive steering wheel free play.
    Technician A says a loose worm bearing preload adjustment may cause the problem.
    Technician B says loose column U-joints may cause the problem.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

23. The engine has recently been replaced in a front-wheel-drive car with power rack and pinion steering. The customer now complains about excessive steering effort. A preliminary check of the steering revealed the fluid level was OK and the belts were not slipping.
    Technician A says perhaps the rack was knocked out of alignment when the engine was installed.
    Technician B says perhaps the pressure line was bent or pinched when the engine was installed.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

24. While discussing rear suspension systems:
    Technician A says semi-independent rear suspension systems momentarily have a slight negative camber and toe-in when the wheel goes over a bump.
    Technician B says constantly carrying a lot of weight in the rear of a car with semi-independent rear suspension may cause the rear tires to wear on the inside edge.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

25. The owner of a 4WD sport utility vehicle complains about wheel thumping and vibration on tight turns at low speed. The most probable cause of this condition is:
    A. Excessive positive scrub radius.
    B. Improper steering axis inclination (SAI).
    C. Transfer case is in 4WD.
    D. Bent steering knuckle.

26. If a power steering system has the specified pump pressure, but steering effort is excessive than specs, all of the following could cause or contribute to the problem EXCEPT:
    A. Worn front tires.
    B. Cold fluid.
    C. Hose restrictions.
    D. Steering gear malfunction.

27. The customer says his vehicle has a rapid "thumping" noise and a vibration in the steering wheel that is most noticeable when the vehicle is at a steady speed in a long curve.
    Technician A says the problem could be caused by a tire defect.
    Technician B says the problem could be improper dynamic wheel balance.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

28. While discussing power steering fluids:
Technician A says a foamy, milky power steering fluid is caused by mixing automatic transmission fluid with hydraulic fluid intended for power steering use.
Technician B says using automatic transmission fluid instead of power steering hydraulic fluids will lower pump pressure and increase steering effort.
Who is correct?
A. Technician A C. Both A and B
B. Technician B D. Neither A nor B

29. On a car with power rack and pinion steering, the steering suddenly swerves to the right or left when a front wheel strikes a road irregularity. The most likely cause of the problem is:
A. A loose rack bearing adjustment.
B. Worn front struts.
C. Loose steering gear mounting bushings.
D. Bent steering arm.

30. A customer returns to your shop and says she just had steering work done on the car the day before, and it has been pulling to the left since then. A check of the records shows that lower control arm ball joints and both rubber-encapsulated tie-rod ends were replaced.
Technician A says the tie-rod end may have been installed with the wheels turned slightly away from center.
Technician B says the alignment should have been checked after installing the ball joints.
Who is correct?
A. Technician A C. Both A and B
B. Technician B D. Neither A nor B

31. When diagnosing an HEV with a scan tool a U0131 is obtained. This DTC indicates a defect in the:
A. Data network.
B. Inverter.
C. Propulsion motor and related circuit.
D. Generator and related circuit.

32. While discussing excessive vehicle noise and vibration:
Technician A says suspension and driveline vibrations may be amplified by the resonance of the body or steering wheel.
Technician B says noises that phase in and out of hearing range may be two separate noises that alternately amplify then cancel each other.
Who is correct?
A. Technician A C. Both A and B
B. Technician B D. Neither A nor B

33. In a four-wheel active steering system (4WAS), when changing lanes at high speed the:
A. Rear wheels are steering a few degrees in the same direction as the front wheels.
B. Rear wheels are steered 5 degrees in the opposite direction to the front wheels.
C. Camber angle is changed on the rear wheels.
D. The rear wheels remain in the straight ahead position.

34. While discussing unibody and frame problems:
Technician A says an indication of possible frame damage is excessive tire wear when the alignment angles are correct.
Technician B says a worn strut lower ball joint is often an indicator of unibody torsional damage.
Who is correct?
A. Technician A C. Both A and B
B. Technician B D. Neither A nor B

35. While discussing frame damage:
Technician A says wrinkles in the upper flange of a truck frame indicate a sag.
Technician B says diamond-shaped distortion of a 4WD sport utility vehicle frame was possibly caused by towing or being towed from a frame corner.
Who is correct?
A. Technician A C. Both A and B
B. Technician B D. Neither A nor B

36. Power steering fluid is leaking from the high-pressure outlet fitting on a nonsubmerged power steering pump. To correct this problem, you should:
A. Replace the cover seal.
B. Replace the O-ring.
C. Replace the fitting.
D. Replace the check valve.

37. The lock cylinder on a light-duty GM truck with an automatic transmission is very hard to turn between "Off" and "Off-Lock." All of the following could cause this problem EXCEPT:
    A. Broken lock-bolt spring.
    B. Distorted lock rack.
    C. Burr on tang of shift gate.
    D. Shift linkage not adjusted.

38. The steering wheel of a GM car is loose in every other tilt position. Of the following possible causes, which is the most likely to cause this problem?
    A. Housing support screws loose.
    B. Column misaligned.
    C. Lock shoe springs broken.
    D. Loose fit of lock shoe to lock pivot pin.

39. While discussing unibody and frame damage:
    Technician A says a vehicle that has been rear-ended could have later problems with steering and tracking.
    Technician B says towing a 2,000 pound trailer on a class II hitch bolted to the frame of a minivan will cause diamond distortion of the frame.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

40. While discussing a Honda Prelude 4WS system:
    Technician A says that before diagnosing the system, the idle speed has to be steady at the specified rpm.
    Technician B says before diagnosing the 4WS system, the rear steering center lock pin must be installed.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

41. A customer says the steering wheel of her front-wheel-drive car does not return to the center position after a turn. A test drive reveals that the steering wheel is stiff and only returns to within approximately 90° of center after a 180° turn.
    Technician A says the problem is memory steer and could be caused by binding in the steering shaft universal joints.
    Technician B says memory steer in a front-wheel-drive car may be also caused by binding upper strut mounts.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

42. A customer says his front-wheel-drive car shakes and moans when decelerating at low speeds. The most likely cause of the problem is:
    A. Worn upper strut bearings.
    B. Worn inner drive axle joints.
    C. Loose wheel bearings.
    D. Excessive tire inflation pressure.

43. A sport utility vehicle with a power recirculating ball steering gear makes a rattling noise when the steering wheel is turned. This noise is noticeable whether the car is in motion or standing still.
    Technician A says the cause of the problem could be a loose pitman arm or shaft.
    Technician B says the cause of the problem could be the high-pressure power steering hose touching some part of the vehicle.
    Who is correct?
    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

44. A rear-wheel-drive car has a steering wander problem. The cause of this problem could be:
    A. Tire tread wear.
    B. Loose outer tie-rod ends.
    C. Worn idler arm.
    D. All of the above.

45. A customer purchased P-metric tires to replace the 6.00–15 tires on his pickup truck.

    Technician A says P-metric tires should not be installed on a vehicle designed to ride on bias-ply tires.

    Technician B says radial tires and belted bias-ply tires should never be mixed on the same axle.

    Who is correct?

    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

46. Many vehicles have too much play in the steering wheel, usually caused by loose steering components. A check of these components should be:
    A. Done with vehicle weight on the tires.
    B. Done with a computerized alignment system.
    C. Completed after a front wheel alignment.
    D. Performed with the vehicle raised and the wheels unsupported.

47. While discussing shock absorber diagnosis:

    Technician A says the "bounce test" is the sure way to quickly pinpoint bad shocks and struts.

    Technician B says oil film on the lower chamber of a shock or strut indicates leakage and requires replacement.

    Who is correct?

    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

48. While discussing front suspension angles:

    Technician A says turning angle is fixed by the steering and suspension system design.

    Technician B says toe-out on turns may be adjusted with the steering stopper bolts.

    Who is correct?

    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

49. While discussing rear suspension alignment:

    Technician A says in straight-ahead driving, the rear wheels must track exactly behind the front wheels or the vehicle will not handle correctly.

    Technician B says a dynamic tracking rear suspension that lets the rear wheels turn in the same direction as the front wheels makes curve negotiation and lane changes much quicker and safer.

    Who is correct?

    A. Technician A C. Both A and B
    B. Technician B D. Neither A nor B

50. When diagnosing a 4WAS system, during the active tests:
    A. The battery pack and 12V battery are tested.
    B. The front and rear wheels are steered to the right at the same time.
    C. The rear wheels are steered a few degrees in each direction.
    B. Specific system components are activated to check component operation.

to convert these	to these	multiply by
TEMPERATURE		
Centigrade Degrees	Fahrenheit Degrees	C degrees x 1.8 +32 = F degrees
Fahrenheit Degrees	Centigrade Degrees	F degrees -32 x .556 = C degrees
LENGTH		
Millimeters	Inches	0.03937
Inches	Millimeters	25.4
Meters	Feet	3.28084
Feet	Meters	0.3048
Kilometers	Miles	0.62137
Miles	Kilometers	1.60935
AREA		
Square Centimeters	Square Inches	0.155
Square Inches	Square Centimeters	6.45159
VOLUME		
Cubic Centimeters	Cubic Inches	0.06103
Cubic Inches	Cubic Centimeters	16.38703
Cubic Centimeters	Liters	0.001
Liters	Cubic Centimeters	1000
Liters	Cubic Inches	61.025
Cubic Inches	Liters	0.01639
Liters	Quarts	1.05672

to convert these	to these	multiply by
Quarts	Liters	0.94633
Liters	Pints	2.11344
Pints	Liters	0.47317
Liters	Ounces	33.81497
Ounces	Liters	0.02957
WEIGHT		
Grams	Ounces	0.03527
Ounces	Grams	28.34953
Kilograms	Pounds	2.20462
Pounds	Kilograms	0.45359
WORK		
Centimeter-Kilograms	Inch-Pounds	0.8676
Inch-Pounds	Centimeter-Kilograms	1.15262
Meter Kilograms	Foot-Pounds	7.23301
Foot-Pounds	Newton-Meters	1.3558
PRESSURE		
Kilograms/Sq. Cm	Pounds/Sq. Inch	14.22334
Pounds/Sq. Inch	Kilograms/Sq. Cm	0.07031
Bar	Pounds/Sq. Inch	14.504
Pounds/Sq. Inch	Bar	0.06895

Automotive Suspension and Steering Systems Special Tool Suppliers

Automotive Group
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Fluke Corporation
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Easco/KD Tools
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Hennessy Industries, Inc.
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Hunter Engineering Company
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OTC Division, SPX Corporation
Owatonna, MN

Sears Industrial Sales
Cincinnati, OH

Snap-On Tools Corporation
Kenosha, WI

Specialty Products Company
Longmont, CO

Federal Mogul Corporation
Ann Arbor MI

Audi diagnostic tool and service information
http://www.audi.ddsltd.com

Chrysler service information:
http://www.techauthority.daimlerchrysler.com

General Motors tool and service information
http://www.gmgoodwrench.com
http://www.acdelco.com

Ford Motor Company vehicle information
http://www.ford.com

Helm Incorporation, distributors of service manuals and training publications for many original equipment manufacturers
http://www.helm.com

Hyundai service publications
http://www.hmaservice.com

Training materials, tools, and equipment
http://www.dealerequipment.com

Special service tools
http://www.spxkentmoore.com

KIA general information
http://www.kia.com

Mac Tools, tool and equipment information
http://www.mactools.com

Nissan service manuals, 2000 and later models
http://www.nissan-techinfo.com

OTC Division of SPX Corporation, tools and equipment information
http://www.otctools.com

Snap-on Tools Corporation, tools and service equipment
http://www.snapondiag.com

Toyota Motor Corporation, vehicles and parts information
http://www.toyota.com

Volkswagen service information
http://www.ddstld.com

Volvo service information, 1999 and later models
http://www.volvovira.com

Service information pre-1999
http://www.volvotechinfo.com

Automotive Service Association (ASA) www.asashop.org
P.O. Box 929
Bedford Texas 76021

International Automotive Technicians Network (iatn) www.iatn.net

Society of Automotive Engineers (SAE) www.sae.org
400 Commonwealth Dr.
Warrendale PA 15096

Moog Service Link www.moogauto.com
Cooper Moog Automotive
P.O. Box 7224
6565 Wells Ave.
St. Louis MO 63177

Glossary
Glosario

Accelerometer An input sensor that senses vehicle acceleration in a computer-controlled suspension system.

Acelerómetro Sensor de entrada que advierte la aceleración del vehículo en un sistema de suspensión controlado por computadora.

Active coils Located in the center area of a coil spring.

Muelles activos Ubicado en el centro de un muelle espiral.

Active suspension system A computer-controlled suspension system with double-acting solenoids at each wheel.

Sistema activo de suspensión Sistema de suspensión controlado por computadora con solenoides de doble acción montados en cada una de las ruedas.

Actuator An electronically operated solenoid in a strut or shock absorber that controls firmness.

Actuador Un solenoide operado electrónicamente en un tirante o un amortiguador que controla la firmeza.

Adaptive cruise control system Maintains a specific distance between the vehicle being driven and the vehicle being followed.

Sistema adaptable de marcha a velocidad de crucero Mantiene una distancia específica entre el vehículo que se conduce y el vehículo que se sigue.

Adjustable strut A strut with a manual-operated adjustment for strut firmness.

Tirante ajustable Un tirante de ajuste operado por mano que determina la firmeza del tirante.

Air bag deployment module The air bag and deployment canister assembly that is mounted in the steering wheel for the driver's side air bag or in the dash panel for the passenger's side air bag.

Unidad de despliegue del Airbag El conjunto del Airbag y elemento de despliegue montado en el volante de dirección para proteger al conductor, o en el tablero de instrumentos para proteger al pasajero.

Air spring An air-filled membrane that replaces the conventional coil springs in an air suspension system.

Muelle de aire Membrana llena de aire que reemplaza los muelles helicoidales convencionales en un sistema de suspensión de aire.

Air spring solenoid valve An electrically operated solenoid that allows air to flow in and out of an air spring.

Muelle de aire con válvula activada por solenoide Solenoide activado eléctricamente que permite el flujo libre de aire en un muelle de aire.

All-season tires Tires with special tread designed to improve traction on snow or ice, while providing acceptable noise levels on smooth road surfaces.

Neumáticos para toda época Neumáticos con una huella especial diseñada para mejorar la tracción en la nieve o en el hielo, a la misma vez que provee niveles aceptables de ruido cuando se conduce el vehículo en un camino cuya superficie es lisa.

American Petroleum Institute (API) An organization in charge of engine oil classifications and many other areas in the petroleum industry.

Instituto Americano del Petróleo (API) Organización que tiene a su cargo la clasificación del aceite de motor y varias otras áreas en la industria del petróleo.

Amplitude The extent of a vibratory movement.

Amplitud El magnitud de un movimiento de vibración.

Analog voltage signal A voltage signal that varies continuously within a specific range.

Señal de voltaje análogo Un señal que varía continuamente dentro de una banda específica.

Angular bearing load A load applied to a bearing in a direction between horizontal and vertical.

Carga del cojinete angular Una carga aplicada a un cojinete en una dirección entre horizontal y vertical.

Antilock brake system (ABS) A computer-controlled brake system that prevents wheel lockup during brake applications.

Sistema antiblocante de frenos Un sistema controlado por computadora que previene el bloqueo en las ruedas durante la aplicación de los frenos.

Asymmetrical An arrangement marked by irregularity such as different shapes, sizes, and positions.

Asimétrico Un arreglo caracterizado por la irregularidad tal como las diferencias de forma, tamaño y posición.

Asymmetrical leaf spring Has the same distance from the spring center bolt to each end of the spring.

Ballesta de hojas asimétricas Tiene la misma distancia desde el perno del centro del resorte a cada extremo del resorte.

Axle windup The tendency of the rear-axle housing to rotate in the opposite direction to the wheel and tire rotation during hard vehicle acceleration.

Bobinado del eje La tendencia de la carcasa del eje trasero de rotar en la dirección opuesta a la rotación de la rueda y el neumático durante la aceleración fuerte del vehículo.

Atmospheric pressure The pressure exerted on the earth by the atmosphere, which is 14.7 psi at sea level.

Presión atmosférica Presión que la atmósfera ejerce sobre la tierra. Dicha presión es 14.7 psi [peso sobre unidad de superficie] al nivel del mar.

Automatic level control (ALC) System maintains the rear suspension trim height regardless of the rear suspension load. If a heavy object is placed in the trunk, the rear wheel position sensors send below trim height signals to the ESC module.

Sistema de **Control de nivel automático (CNA)** Mantiene la altura del centrado de la suspensión trasera sin tomar en cuenta la carga de la suspensión trasera. Si un objeto se coloca en la cajuela, los sensores de posición de la rueda trasera envían señales de altura por debajo del centrado al módulo de CSE.

Axle offset A condition in which the complete rear axle assembly has turned so one rear wheel has moved forward and the opposite rear wheel has moved rearward.

Descentralización del eje Condición que ocurre cuando todo el conjunto del eje trasero ha girado de manera que una de las ruedas traseras se ha movido hacia adelante y la opuesta se ha movido hacia atrás.

Axle sideset A condition in which the rear axle assembly has moved sideways from its original position.

Resbalamiento lateral del eje Condición que ocurre cuando el conjunto del eje trasero se ha movido lateralmente desde su posición original.

Axle thrustline Is a line extending forward from the center of the rear axle at a 90° angle.

Eje de directriz de presiones Es una línea que se extiende hacia enfrente desde el centro del eje trasero a un ángulo de 90°.

Axle tramp The repeated lifting of the differential housing during extremely hard acceleration.

Barreta del eje Levantamiento repetido del alojamiento del diferencial durante una aceleración sumamente rápida.

Ball bearings Have round steel balls between the inner and outer races.

Cojinete de bolas Tiene bolas de acero entre las carreras interiores y exteriores.

Bead filler A piece of rubber positioned above the bead that reinforces the sidewall and acts as a rim extender.

Relleno de la pestaña de la llanta Pieza de caucho ubicada sobre la pestaña que sirve para reforzar la pared lateral y actúa como una extensión de la llanta.

Bead wire A group of circular wire strands molded into the inner circumference of the tire that anchors the tire on the rim.

Cable de pestaña Grupo de cordones circulares de cables moldeados en la circunferencia interior del neumático que sujetan el neumático a la llanta.

Bearing hub unit A complete wheel bearing and hub unit to which the wheel rim is bolted.

Conjunto de cubo y cojinete Conjunto total de cojinete y cubo de rueda al que se emperna la llanta de la rueda.

Bearing seals Circular metal rings with a sealing lip on the inner edge. Bearing seals are usually mounted on both sides of a bearing to prevent dirt and moisture from entering the bearing while sealing the lubricant in the bearing.

Juntas de estanqueidad del cojinete Anillos metálicos circulares con un reborde de estanqueidad en el borde interior. Normalmente las juntas de estanqueidad del cojinete se montan en ambos lados de un cojinete para evitar la entrada de suciedad y humedad mientras sellan el lubricante dentro del mismo.

Bearing shields Circular metal rings attached to the outer race that prevent dirt from entering the bearing but allow excess lubricant to flow out of the bearing.

Protectores para cojinetes Anillos metálicos circulares fijados a la arandela exterior que evitan la entrada de suciedad al cojinete, pero permiten la salida de exceso de lubricante del mismo.

Belt cover A nylon cover positioned over the belts in a tire that helps to hold the tire together at high speed, and provides longer tire life.

Cubierta de correa Cubierta de nilón ubicada sobre las correas de un neumático. Esta cubierta ayuda a conservar la solidez del neumático cuando se conduce el vehículo a gran velocidad, además de proporcionarle mayor durabilidad.

Belted bias-ply tire A type of tire construction with the cord plies wound at an angle to the center of the tire, and fiberglass or steel belts mounted under the tread area of the tire.

Neumático de correas con estrías diagonales Tipo de neumático fabricado con estrias arregladas a un ángulo con respecto al centro del neumático, y correas de fibra de vidrio o de acero montadas debajo de la huella del mismo.

Bias-ply tire A type of tire construction with the cord plies wound at an angle to the center of the tire and no belts surrounding the cords.

Neumático de estrías diagonales Un tipo de construcción de neumático con estrías arregladas en un ángulo con respecto al centro del neumático y sín correas envolviendo las estrías.

Brake-by-wire A computer-controlled brake system with no direct mechanical connection between the brake pedal and the master cylinder.

Frenado alámbrico Un sistema de frenos controlado por computadora sin una conexión mecánica directa entre el pedal de freno y el cilíndro maestro.

Brake pressure modulator valve (BPMV) A group of solenoid valves mounted in a single valve body that controls fluid pressure in the brake system during antilock brake, traction control, and vehicle stability control functions.

Válvula moderador de presión de frenado (BPMV) Un grupo de válvulas de solenoide montado en una sóla caja de válvula que controla la presión de los fluidos en el sistema de frenos durante las operaciones de freno antibloqueante, control de tracción, y control de la estabilidad del vehículo.

Brake pressure switch An electrical switch operated by brake fluid pressure.

Interruptor de presión del freno Interruptor eléctrico activado por la presión del disco de freno.

Braking and deceleration torque The torque applied to the rear axle assembly during deceleration and braking in a rear wheel drive vehicle.

Torsión de deceleración y frenaje La torsión impuesta en el ensamblado del eje trasero durante la deceleración y el frenado en un vehículo de tracción trasera.

Breather tube A small metal tube that allows air to flow between the bellows boots in a rack and pinion steering gear during a turn.

Tubo respiradero Pequeño tubo metálico que permite el flujo libre de aire entre las botas de fuelles en un mecanismo de dirección de cremallera y piñón durante un viraje.

Bump steer The tendency of the steering to veer suddenly in one direction when one or both front wheels strike a bump.

Cambio de dirección ocacionado por promontorios en el terreno Tendencia de la dirección a cambiar repentinamente de sentido cuando una o ambas ruedas delanteras golpea un promontorio.

Cam ring A metal ring with an elliptical-shaped inner surface on which the vanes make contact in a power steering pump.

Anillo de levas Un anillo metálico con una superficie interior de forma elíptica en la cual las aletas hacen contacto en una bomba de dirección hidraulica.

Car access system (CAS) A system that controls specific vehicle functions and operates in conjunction with the safety and gateway module on a vehicle with an active steering system.

Sistema de acceso al automóvil (CAS, en inglés) Un sistema que controla las funciones específicas del vehículo y que opera en conjunción con el módulo de la puerta de enlace y de seguridad de un vehículo con un sistema de dirección activo.

Carbon dioxide (CO2) A greenhouse gas that is a byproduct of gasoline or diesel fuel combustion.

Dióxido de carbono (CO2) Un gas de efecto invernadero que es un subproducto de la combustión de la gasolina o del combustible diesel.

Caster angle The angle between an imaginary line through the center of the tire and wheel and another imaginary line through the centers of the lower ball joint and upper strut mount viewed from the side.

ángulo de inclinación El ángulo entre una línea imaginaria que pasa por el centro de un neumático y la rueda y otra línea que pasa por los centros de la articulación esférica inferior y la montadura superior del apoyadero visto de un lado.

Center link A long rod connected from the pitman arm to the idler arm in a steering linkage.

Biela motriz central Varilla larga conectada del brazo pitman al brazo auxiliar en un cuadrilátero de la dirección.

Channel frame A type of frame construction in which a steel channel is positioned on the top and bottom of the vertical frame web.

Armazón fabricado con ranuras Tipo de fabricación del armazón en la que una ranura de acero es colocada en las partes superior e inferior de la malla del armazón vertical.

Clock spring electrical connector A conductive ribbon in a plastic case mounted on top of the steering column that maintains electrical contact between the air bag inflator module and the air bag electrical system.

Conector eléctrico de cuerda de reloj Cinta conductiva envuelta en una cubierta plástica montada en la parte superior de la columna de dirección, que mantiene contacto eléctrico entre la unidad infladora y el sistema eléctrico del Airbag.

Collision mitigation system Operates specific vehicle functions to help prevent a collision.

Sistema de alivio de colisiones Opera funciones especificas dei vehiculo para ayudar a evitar una colisión.

Column-drive EPS Has an electric assist motor coupled to the steering shaft in the steering column.

Transmisión de columna de GPE (guiado de propulsión electrónica) Tiene un motor de corriente eléctrica que acompaña al eje de dirección en la columna de la dirección.

Compact spare tire A spare tire and wheel that is much smaller than the other tires on the vehicle, and is designed for short-distance driving at low speed.

Neumático compacto de repuesto Conjunto de neumático y rueda de repuesto mucho más pequeño que los demás neumáticos del vehículo, diseñado para viajes de corta distancia a poca velocidad.

Complete box frame A type of vehicle frame shaped like a rectangular steel box.

Fabricación completa Tipo de armazón en forma de caja rectangular de acero.

Compressible A substance is compressible when an increase in pressure causes a decrease in volume.

Compresibile Una sustancia es compresible cuando un aumento en la presión produce una disminución en el volumen.

Compression loaded A suspension ball joint mounted so the vehicle weight is forcing the ball into the joint.

Cargada de presión Junta esférica de la suspensión montada de manera que el peso del vehículo presiona la bola hacia el interior de la junta.

Cord plies Surround both tire beads and extend around the inner surface of the tire to enable the tire to carry its load.

Pliegues de cuerda Rodean ambas cejas de los neumáticos y se extienden alrededor de la superficie interor del neumático para permitir que el nuemático soporta su carga.

Cross-axis ball joints Contain large insulating bushings in place of typical ball joints.

Articulaciones de rótula a través del eje Contienen pasa tapas grandes en lugar de las rótulas esféricas comunes.

Cycle A series of events that repeat themselves regularly.

Ciclo Una serie de eventos que se repitan regularmente.

Damper solenoid valve An electronically operated hydraulic valve that controls shock absorber or strut damping.

Válvula amortiguador del solenoide Una válvula hidráulica operada electronicamente que controla el amortiguador o el amortiguamiento del apoyadero.

Diamond-frame condition A frame that is diamond-shaped from collision damage.

Condición forma de diamante del armazón Armazón que ha adquirido la forma de un diamante a causa del impacto recibido durante una colisión.

Digital motor electronics (DME) A computer that controls specific vehicle functions and operates in conjunction with the safety and gateway module on a vehicle with an active steering system.

Sistema electrónico digital del motor (DME, en inglés) Una computadora que controla funciones específicas del vehículo y opera en conjunción con el módulo de la puerta de enlace y de seguridad de un vehículo con un sistema de dirección activo.

Digital voltage signal A voltage signal that is either high or low.

Señal digital de tensión Señal de tensión que es alta o baja.

Directional stability The tendency of the vehicle steering to remain in the straight-ahead position when driven straight ahead on a smooth level road surface.

Estabilidad direccional Tendencia de la dirección del vehículo a permanecer en línea recta al ser así conducido en un camino cuya superficie es lisa y nivelada.

Double-row ball bearing A bearing with two adjacent rows of circular steel balls.

Cojinete de bolas de doble hilera Cojinete que contiene dos hileras adyacentes de bolas circulares de acero.

Double wishbone rear suspension system A multilink suspension system in which the links may be shaped like a wishbone.

Suspensión trasera de doble horquilla Sistema de suspensión de empalme múltiple en el que a las bielas motrices se les puede dar forma de espoleta.

Dynamic balance The balance of a wheel in motion.

Equilibrio dinámico Equilibrio de una rueda en movi-miento.

Electronically controlled orifice (ECO) valve A computer-controlled solenoid valve in the power steering pump that controls fluid flow from the pump to the servotronic valve.

Válvula de orificio controlado electrónicamente (ECO, en inglés) Una válvula solenoide controlada por computadora que se encuentra en la bomba de dirección de potencia que controla el flujo de fluidos desde la bomba hasta la válvula servotrónica.

Electronically controlled 4WS system A four-wheel steering system in which the rear wheel steering is controlled electronically.

Dirección en las cuatro ruedas controlada electrónicamente Sistema de dirección en las cuatro ruedas en el que la dirección de la rueda trasera se controla electrónicamente.

Electronic brake and traction control module (EBTCM) A module that controls antilock brake, traction control, and vehicle stability control functions.

Módulo electrónico de control de freno y tracción (EBTCM) Un módulo que controla las funciones de control del freno antibloqueo, control de tracción, y la estabilidad del vehículo.

Electronic control unit (ECU) A computer that receives input signals and controls output functions.

Unidad de control electrónico (ECU, en inglés) Una computadora que recibe señales de entrada y controla las funciones de salida.

Electric locking unit (ELU) Locks the worm drive and drive motor in an active steering system if a safety-related defect occurs.

Unidad de bloqueo eléctrico (ELU, en inglés) Bloquea la transmisión por tornillo sinfín y el motor de impulsión de un sistema de dirección activo si se produce un defecto relacionado con la seguridad.

Electronic rotary height sensor Has an internal rotating element and this sensor sends voltage signals to the control module in relation to the curb riding height.

Sensores electrónicos rotativos de altura Tienen un elemento rotativo interno, y estos sensores envían señales de voltaje al módulo de control con relación a la curva de la altura de rodaje.

Electronic suspension control (ESC) system Controls damping forces in the front struts and rear shock absorbers in response to various road and driving conditions.

Sistema de control de suspensión electrónica (CSE) Controla las fuerzas de amortiguamiento en las barras transversales frontales y los amortiguadores neumáticos traseros como respuesta a las variadas condiciones de manejo y del camino.

Electronic variable orifice (EVO) steering A computer-controlled power steering system in which the computer operates a solenoid to control power steering pump pressure in relation to vehicle speed.

Dirección de orificio variable electrónico Sistema de dirección hidráulica controlado por computadora en el que la computadora activa un solenoide para controlar la presión de la bomba de la dirección hidráulica de acuerdo a la velocidad del vehículo.

Electronic vibration analyzer (EVA) A tester that measures vibration amplitude.

Analizador electrónico de vibraciones (EVA) Un comprobador que mide el amplitud de las vibraciones.

Encoded disc Works with an optical steering angle sensor to supply a voltage signal in relation to steering wheel rotation.

Disco codificado Funciona con un sensor de ángulo de la dirección óptico para proporcionar una señal de voltaje en relación con la rotación del volante.

Energy The ability to do work.

Energía Capacidad para realizar un trabajo.

Energy-absorbing lower bracket A steering column bracket that protects the driver by allowing the column to move away from the driver when impacted by the driver in a collision.

Soporte absorbente de energía Un soporte de la columna de dirección que proteja al conductor permitiendo que la columna se aleja del conductor cuando éste la golpea en una colisión.

Faster steering A steering gear that turns the front wheels from lock-to-lock with less steering wheel rotation.

Dirección más rápida Mecanismo de dirección que gira las ruedas delanteras de un extremo al otro con menos movimiento del volante de dirección.

Feel of the road A feeling experienced by a driver during a turn when the driver has a positive feeling that the front wheels are turning in the intended direction.

Sensación del camino Sensación experimentada por un conductor durante un viraje cuando está completamente seguro de que las ruedas delanteras están girando en la dirección correcta.

Firm relay A relay in a computer-controlled suspension system that supplies voltage to the strut actuators and moves these actuators to the firm position.

Relé de fijación Relé en un sistema de suspensión controlado por computadora que le provee tensión a los accionadores de los montantes y los lleva a una posición fija.

Flow control valve A special valve that controls fluid movement in relation to system demands.

Válvula de control de flujo Válvula especial que controla el movimiento del fluido de acuerdo a las exigencias del sistema.

Fluted lip seal A seal lip with fine grooves that direct the lubricant back into the reservoir rather than leaking past the seal lip.

Junta de estanqueidad de reborde estriado Reborde de una junta de estanqueidad con ranuras finas que dirigen el lubricante hacia el tanque en vez de permitir que el mismo se escape del reborde.

Force Implies the exertion of strength, which may be physical or mechanical.

Fuerza Implica el esfuerzo excesivo físico o mecánico.

Four-wheel alignment Measurement and adjustment of wheel alignment angles at the front and rear wheels.

Alineación de cuatro ruedas La medida y el ajuste de los ángulos de alineación de las ruedas en las ruedas delanteras y traseras.

Four-wheel active steering (4WAS) A steering system in which the rear wheels are steered electronically in relation to the front wheel steering angle and vehicle speed.

Dirección activa con tracción en las cuatro ruedas (4WAS, en inglés) Un sistema de dirección en el que las ruedas traseras se direccionan electrónicamente en relación con el ángulo de dirección de las ruedas delanteras y la velocidad del vehículo.

Four-wheel steering (4WS) A steering system in which both the front and rear wheels turn right or left to steer the vehicle.

Dirección en las cuatro ruedas Sistema de dirección en el que tanto las ruedas traseras como las delanteras giran hacia la derecha o la izquierda para dirigir el vehículo.

Frame buckle A frame that is accordion-shaped to some extent from collision damage.

Encorvamiento del armazón Armazón que ha adquirido la forma de un acordeón a causa del impacto recibido durante una colisión.

Frame sag A frame that is bent downward in the center from collision damage.

Hundimiento del armazón Armazón torcido hacia abajo en el centro a causa del impacto recibido durante una colisión.

Frame twist A frame that is bent from collision damage so one corner is higher in relation to the opposite corner.

Torcedura del armazón Armazón torcido a causa del impacto recibido durante una colisión; como resultado de esta torcedura un ángulo será más alto con relación al ángulo opuesto.

Friction The resistance to motion when the surface of one object is moved over the surface of another object.

Fricción Resistencia al movimiento cuando la superficie de un objeto se mueve sobre la superficie de otro.

Full-wire open-end springs Coil spring ends that are cut straight off and sometimes flattened, squared, or ground to a D-shape.

Muelles de extremo abierto con cable cerrado Extremos de muelles helicoidales cortados en línea que a veces son aplanados, cuadrados o afilados en forma de D.

Garter spring A circular spring behind a seal lip.

Muelle jarretera Muelle circular ubicado detrás de un reborde de una junta de estanqueidad.

Gas-filled shock absorber Contains a gas charge and hydraulic fluid.

Amortiguadore lleno de gas Contienens una carga de gas y fluido hidráulico.

Gear ratio The relationship between the drive gear and driven gear in a gear set.

Relación de engranaje La relación entre el engranaje de impulso y el engranaje mandado en un juego de engranajes.

Gear tooth backlash Movement between gear teeth that are meshed together.

Juego entre los dientes del engranaje Movimiento entre los dientes del engranaje que están endentados entre sí.

Geometric vehicle centerline An imaginary line through the exact center of the front and rear wheels.

Linea de eje central geométrica Línea imaginaria a través del centro exacto de las ruedas delanteras y traseras.

Geometric centerline The exact centerline of the vehicle chassis.

Línea central geométrica La línea central exacta del chasis del vehículo.

Geometric centerline alignment A wheel alignment procedure in which the front wheel toe is adjusted to specifications using the geometric centerline as a reference.

Alineación de la línea central geométrica Procedimiento de alineación de las ruedas en el que se ajusta el tope de la rueda delantera según las especificaciones utilizando la línea central geométrica como punto de referencia.

Greenhouse gas A gas that helps to form a blanket above the earth's atmosphere.

Gas de efecto invernadero Un gas que ayuda a formar un manto por encima de la atmósfera de la tierra.

Gussets Pieces of metal welded into a corner where two pieces of metal meet to increase component strength.

Esquinero Las piezas de metal soldadas en una esquina en donde se juntan dos piezas de metal para aumenter la fuerza del componente.

Hall element Is an electronic device that produces a voltage signal when the magnetic field approaches or moves away from the element.

Elemento Hall Es un dispositivo electrónico que produce una señal de voltaje cuando el campo magnético se acerca o se aleja del elemento.

Heavy-duty coil spring Compared with conventional coil springs, heavy-duty springs have larger wire diameter and 3% to 5% greater load-carrying capability.

Muelle helicoidal para servicio pesado Comparado con los muelles helicoidales convencionales, los muelles para servicio pesado tienen cables de diámetro más grande y una capacidad de carga de un 3% a un 5% mayor.

Heavy-duty shock absorbers Compared with conventional shock absorbers, heavy-duty shock absorbers have improved seals, a single tube to reduce heat, and a rising rate valve for precise spring control.

Amortiguadores para servicio pesado Comparados con los amortiguadores convencionales, los amortiguadores para servicio pesado tienen juntas de estanqueidad mejoradas, un tubo único para reducir el calor, y una válvula de vástago ascendente para un control preciso del muelle.

Height sensor Sends a signal to the suspension computer in relation to chassis height.

Sensor de altura Envía una señal a la computadora de suspensión referente a la altura del chasis.

Helical gear teeth Are positioned at an angle in relation to the gear centerline.

Dientes de engranaje helicoidales Ubicados a un ángulo con relación a la línea central del engranaje.

Hertz A measurement for the speed at which an electronic signal or vibration cycles from high to low.

Hercio Una medición de la velocidad a la cual una señal electrónica o una vibración pasa de alta a baja.

High-frequency transmitter An electronic device that sends high-frequency voltage signals to a receiver. Some wheel sensors on computer-controlled wheel aligners send high-frequency signals to a receiver in the wheel aligner.

Transmisor de alta frecuencia Un dispositivo electróncio que manda las señales de alta frecuencia a un receptor. Algunos sensores de ruedas en los alineadores de ruedas controlados por computadora mandan los señales de alta frecuencia a un receptor en el alineador de ruedas.

High-strength steels (HSS) Steels that have above-average strength compared with other body components. High-strength steels are used in some unitized body parts.

Aceros de alta resistencia (HSS) Los aceros que tienen una resistencia superior a lo normal comparado a los otros componentes de la carrocería. Los aceros de alta resistencia se usan en algunos partes de un monocasco.

Hold valve A valve that prevents fluid return to the master cylinder during traction control or vehicle stability control functions.

Válvula de retención Una válvula que previene que los fluidos regresan al cilíndro maestro duante las funciones de control de tracción o control de estabilidad del vehículo.

Horsepower A measurement for the amount of power delivered by an internal combustion engine or an electric motor.

Caballo de fuerza Una medida de la cantidad de potencia entregada por un motor de combustión interna o por un motor eléctrico.

Hybrid vehicles Have two power sources that can supply torque to the drive wheels. In most applications the two power sources are a gasoline engine and an electric motor(s).

Vehículos híbridos Tienen dos fuentes de potencia que pueden proporcionar par motor a las ruedas de arranque. En la mayoría de las aplicaciones las dos fuentes de potencia son los motores de gasolina y eléctricos.

Hydroboost power-assisted steering system Uses fluid pressure from the power steering pump to supply brake power assistance.

Sistema de dirección asistido hidráulicamente Utiliza la presión del fluido de la bomba de la dirección hidráulica para reforzar la potencia del freno.

Hydro-forming Is the process of using extreme fluid pressure to shape metal.

Hidroformación Es el proceso de usar presión extrema de líquidos para darle forma a un metal.

Hydroplaning Occurs when water on the pavement is allowed to remain between the pavement and the tire tread contact area. This action reduces friction between the tire tread and the road surface, and can contribute to a loss of steering control.

Hidrodeslizamiento Sucede cuando se deja agua entre el pavimento y la superficie de rodadura. Esta acción reduce la fricción entre la superficie de rodadura y la superficie del camino, y puede contribuir a una pérdida de control en la dirección.

Idler arm A short, pivoted steering arm bolted to the vehicle frame and connected to the steering center link.

Brazo auxiliar Brazo de dirección corto y articulado, empernado al armazón del vehículo y conectado a la biela motriz central de dirección.

Inactive coils Inactive coils located at the top and bottom ends of a coil spring introduce force into the spring when a wheel strikes a road irregularity.

Bobinas inactivas Las bobinas inactivas localizadas en las extremidades superiores e inferiores de un resorte helicoidal introducen la fuerza en el resorte cuando una rueda choque contra una irregularidad en el camino.

Included angle The sum of the camber and steering axis inclination (SAI) angles.

Ángulo incluído La suma de los ángulos de la inclinación y la inclinación del eje de dirección (SAI).

Independent rear suspension A rear suspension system in which one rear wheel moves upward or downward without affecting the opposite rear wheel.

Suspensión trasera independiente Sistema de suspensión trasera en el que una rueda trasera se mueve de manera ascendente o descendente sin afectar la rueda trasera opuesta.

Inertia The tendency of an object to remain at rest, or the tendency of an object to stay in motion.

Inercia La tendencia de un objeto a permanecer inmóvil, o la tendencia de un objeto a continuar en movimiento.

Inner race The race in the center of a ball or tapered roller bearing that supports the balls or rollers.

Anillo interior El anillo en el centro de una bola o de un cojinete de rodillos cónicos que apoya las bolas o los rodillos.

Integral power-assisted steering system A power steering system in which the power-assisted components are integral with the steering gear.

Sistema de dirección de astencia hidráulica integral Sistema de dirección hidráulica en el que los componentes asistidos forman parte integral del mecanismo de dirección.

Integral reservoir A reservoir that is part of the power steering pump.

Tanque de la bomba Tanque que forma parte de la bomba de la dirección hidráulica.

Interference fit A precision fit between two components that provides a specific amount of friction between the components.

Ajuste a interferencia Ajuste de precisión entre dos componentes que provee una cantidad específica de fricción entre los mismos.

Jounce travel Upward wheel and suspension movement.

Sacudida Movimiento ascendente de la rueda y de la suspensión.

Kickback A force supplied to the steering wheel when one of the front wheels strikes a road irregularity.

Contragolpe Fuerza que se le suministra al volante de dirección cuando una de las ruedas delanteras golpea una irregularidad en el camino.

King pin inclination (KPI) The angle of a line through the center of the king pin in relation to the true vertical centerline of the tire viewed from the front of the vehicle.

Inclinación de la clavija maestra Ángulo de una línea a través del centro de la clavija maestra con relación a la línea central vertical real del neumático vista desde la parte frontal del vehículo.

Ladder frame design A frame with crossmembers between the side rails. These crossmembers resemble steps on a ladder.

Diseño de armazón de tipo escalera Armazón con travesaños entre las vigas laterales. Dichos travesaños se parecen a los peldaños de una escalera.

Lane departure warning (LDW) system Warns the driver if the vehicle drifts out of the lane in which it is driven.

Sistema de advertencia de salida del carril (LDW, en inglés) Advierte al conductor si el vehículo se aparta del carril en el que se está desplazando.

Lateral accelerometer Sends a voltage signal to the vehicle stability control computer in relation to lateral rear chassis movement.

Acelómetro lateral Manda una señal de voltaje a la computador de control de estabilidad del vehículo en relación con el movimiento lateral del trasero del chasis.

Lift/dive input A computer-controlled suspension system input signal regarding front end lift during acceleration and front end dive while braking.

Señal de entrada de ascenso y descenso Señal de entrada del sistema de suspensión controlado por computadora referente al ascenso del extremo delantero durante la aceleración y al descenso del extremo delantero durante el frenado.

Light-emitting diode (LED) A diode that emits light when current flows through the diode.

Diodo emisor de luz (LED) Diodo que emite luz cuando una corriente fluye a través del mismo.

Linear-rate coil spring A coil spring with equal spacing between the coils, one basic shape, and constant wire diameter. These springs have a constant deflection rate regardless of load. If 200 pounds compress the spring 1 inch, 400 pounds compress the spring 2 inches.

Muelle helicoidal de capacidad lineal Muelle helicoidal con separación igual entre los espirales, una forma básica, y un diámetro de cable constante. Estos muelles tienen una capacidad de desviación constante sin importar la carga. Si 200 libras comprimen el muelle una pulgada, 400 libras comprimen el muelle 2 pulgadas.

Liner A synthetic gum rubber layer molded to the inner surface of a tire for sealing purposes.

Revestimiento Capa de caucho sintético moldeada en la superficie interior de un neumático para sellarlo herméticamente.

Lithium-based grease A special lubricant that is used on the rack bearing in manual rack and pinion steering gears.

Grasa con base de litio Lubricante especial utilizado en el cojinete de la cremallera en mecanismos de dirección de cremallera y piñón manuales.

Load-carrying ball joint A ball joint that supports the weight of the chassis.

Junta esférica con capacidad de carga Junta esférica que apoya el peso del chasis.

Load-leveling shock absorbers Shock absorbers to which air pressure is supplied to increase their load-carrying capability.

Amortiguadores con nivelación de carga Amortiguadores a los que se suministra presión de aire para aumentar su capacidad de carga.

Load rating A rating that indicates the load-carrying capability of a tire.

Clasificación de carga Clasificación que indica la capacidad de carga de un neumático.

Lock-to-lock A complete turn of the front wheels from full right to full left, or vice versa.

Vuelta completa de las ruedas Viraje completo de las ruedas delanteras desde la extrema derecha hasta la extrema izquierda, o viceversa.

Lower vehicle command A command, or signal, sent from a height sensor to the suspension computer that indicates the suspension height must be lowered.

Orden para bajar el vehículo Orden o señal enviada desde un sensor de altura a la computadora del sistema de suspensión que indica que debe bajarse la altura de la suspensión.

MacPherson strut front suspension system A suspension system in which the strut is connected from the steering knuckle to an upper strut mount, and the strut replaces the shock absorber.

Sistema de suspensión delantera de montante MacPherson Sistema de suspensión en el que el montante se conecta del muñón de dirección a un montaje del montante superior; el montante reemplaza el amortiguador.

Magnasteer system A power steering system that varies the steering effort in relation to vehicle speed.

Sistema Magnasteer Un sistema de dirección de potencia que varía el esfuerzo de dirección en relación con la velocidad del vehículo.

MagneRide system A suspension system with computer-controlled shock absorbers containing magneto-rheological fluid.

Sistema MagneRide Un sistema de suspensión con amortiguadores controlados por computadora que contienen fluido magneto-reológico.

Magnesium alloy wheels Wheels manufactured from magnesium mixed with other metals.

Ruedas de aleación de magnesio Ruedas fabricadas con magnesio mezclado con otros metales.

Magneto-rheological fluid (MR fluid) A synthetic fluid that contains numerous small, suspended metal particles. It can be found in some electronically controlled shock absorbers and struts.

Líquido magnetorreológico Líquido sintético que contiene numerosas partículas metálicas suspendidas y pequeñas. Puede encontrarse en algunos amortiguadores y barras transversales electrónicamente controlados.

Mass The measurement of an object's inertia.

Masa La medida de la inercia de un objeto.

Memory steer Occurs when the steering does not return to the straight-ahead position after a turn, and the steering attempts to continue turning in the original turn direction.

Dirección de memoria Condición que ocurre cuando la dirección no regresa a la posición de línea recta después de un viraje, y la dirección intenta continuar girando en el sentido original.

Momentum An object gains momentum when a force overcomes static inertia and moves the object.

Impulso Un objeto cobra impulso cuando una fuerza supera la inercia estática y mueve el objeto.

Mono-leaf spring A leaf spring with a single leaf.

Muelle de lámina singular Muelle de lámina con una sola hoja.

Motorist Assurance Program (MAP) A program that establishes uniform parts inspection guidelines to improve customer satisfaction with the automotive industry.

Programa de aseguranza del conductor (MAP) Una programa que establece los requerimientos uniformes de la inspección de partes para mejorar la satisfacción del cliente con la industria automotríz.

Mud and snow tires Tires with a special tread that provides improved traction when driving in mud or snow.

Neumáticos para condiciones de lodo y nieve Los neumáticos que tienen una huella especial que provee tracción mejorada para conducir en el lodo o la nieve.

Multilink front suspension A suspension system in which the top of the knuckle is supported by two links connected to the chassis.

Suspensión delantera de bielas múltiples Un sistema de suspensión en el cual la parte superior del muñon se soporta por las dos bielas conectadas al \chasis.

Multiple-leaf spring A leaf spring with more than one leaf.

Muelle de láminas múltiples Muelle de lámina con más de una hoja.

Natural vibration frequencies The frequency at which an object tends to vibrate.

Frecuencias de vibración naturales La frecuencia a la cual tiende a vibrar un objeto.

Needle roller bearing A bearing containing small circular rollers.

Cojinete de rodillos con agujas Cojinete que contiene rodillos circulares pequeños.

Negative camber Occurs when the camber line through the center of the tire is tilted inward in relation to the true vertical centerline of the tire viewed from the front of the vehicle.

Combadura negativa Condición que ocurre cuando la combadura a través del centro de un neumático se inclina hacia adentro con relación a la línea central vertical real del neumático vista desde la parte frontal del vehículo.

Negative caster Is the angle of a line through the center of the tire that is tilted forward in relation to the true vertical centerline of the tire viewed from the side.

Avance negativo del pivote de la rueda Es el ángulo de una línea a través del centro de la llanta que está inclinado hacia enfrente en relación con la verdadera línea central vertical de la rueda vista por un lado.

Negative-phase steering Occurs when the rear wheels are steered in the opposite direction to the front wheels.

Dirección de fase negativa Se aplica al modo cuando las ruedas traseras se mueven en dirección opuesta a las ruedas frontales.

Negative scrub radius Is present when the steering axis inclination line meets the road surface outside the true vertical centerline of the tire at the road surface.

Radio matorral negativo Condición que ocurre cuando la inclinación del pivote de dirección entra en contacto con la superficie del camino fuera de la línea central vertical real del neumático en la superficie del camino.

Negative offset Occurs when the wheel centerline is located outboard from the vertical wheel mounting surface.

Desfasaje negativo Se produce cuando la línea central está ubicada fuera de la superficie vertical de montaje de la rueda.

Network Data-transmitting wires that interconnect various computers on a vehicle.

Red Cables que transmiten datos que interconectan diversas computadoras de un vehículo.

Neutral phase steering Occurs when the rear wheels are centered in the straight-ahead position on a four-wheel steering system.

Direccional de fase neutral Sucede cuando las ruedas traseras se centran en una posición hacia enfrente.

Nitrogen tire inflation Tires inflated with nitrogen rather than air.

Inflado de neumáticos con nitrógeno Neumáticos inflados con nitrógeno en lugar de aire.

Non-load-carrying ball joint A ball joint that maintains suspension component location, but does not support the chassis weight.

Junta esférica sin capacidad de carga Junta esférica que mantiene la ubicación del componente de la suspensión, pero no apoya el peso del chasis.

Occupational Safety and Health Administration (OSHA) Regulates working conditions in the United States.

Dirección para Seguridad y Salud Industrial Rige las condiciones de trabajo en los Estados Unidos.

Outer race The outer part of a bearing that supports the balls or tapered rollers.

Anillo exterior La parte exterior de un cojinete que apoya las bolas o los cojinetes de rodillo cónico.

Outlet fitting venturi A narrowing of the passage through the outlet fitting in a power steering pump.

Conexiones de salida venturi Estrechamiento del pasaje a través de la conexión de salida en la bomba de la dirección hidráulica.

Parallel HEVs A hybrid electric vehicle in which the drive wheels may be driven by the internal combustion engine, electric motor, or both.

HEV paralelos Un vehículo híbrido eléctrico en el cual las ruedas motrices se pueden impulsar mediante el motor de combustión interno, el motor eléctrico o ambos.

Parallelogram steering linkage A steering linkage in which the tie-rods are parallel to the lower control arms.

Cuadrilátero de la dirección en paralelograma Cuadrilátero de la dirección en el que las barras de acoplamiento son paralelas a los brazos de mando inferiores.

Perimeter-type frame A vehicle frame in which the side rails are bent outward so these rails are near the side of the body.

Armazón de tipo perímetro Armazón del vehículo en el que las vigas laterales están dobladas hacia afuera para que queden cerca del lado de la carrocería.

Photo diode A diode that provides a voltage signal when light shines on the diode. The light source may be a light-emitting diode (LED).

Fotodiodo Diodo que provee una señal de tensión cuando es iluminado por la luz. La fuente de luz puede ser un diodo emisor de luz (LED).

Pigtail spring ends An end of a coil spring that is wound to a smaller diameter.

Extremos de muelle enrollados en forma de espiral Extremo de un muelle helicoidal devanado a un diámetro más pequeño.

Pinion The drive gear in rack and pinion steering gear.

Piñón Engranaje de mando en el mecanismo de dirección de cremallera y piñón.

Pinion angle sensor Provides a voltage signal in relation to steering pinion position.

Sensor de ángulo del piñón Proporciona una señal de voltaje de acuerdo con la posición del piñón de dirección.

Pinion-drive EPS The electric motor is coupled to the steering gear pinion.

GPE(guiado de propulsión electrónica) por tracción del piñón El motor eléctrico acompaña al piñón de la dirección.

Pitman arm A short steel arm connected from the steering gear sector shaft to the steering center link.

Brazo pitman Brazo corto de acero conectado del árbol del mecanismo de dirección a la biela motriz central de dirección.

Pitman shaft sector A shaft in a recirculating ball steering gear that is connected to the pitman shaft, and the gear teeth on the sector shaft are meshed with the worm gear.

Sector de eje pitman Un eje de un engranaje de bola recirculatoria que se conecta al eje pitman, y los dientes del engranaje del eje del sector se endentan con el engranaje sinfín.

Positive camber Occurs when the camber line through the centerline of the tire is tilted outward in relation to the true vertical tire centerline viewed from the front.

Combadura positiva Condición que ocurre cuando la combadura a través de la línea central del neumático se inclina hacia afuera con relación a la línea central vertical real vista desde la parte frontal.Is the angle of a line through the center of the tire that is tilted rearward in relation to the true vertical centerline of the tire viewed from the side.

Positive caster Is the angle of a line through the center of the tire that is tilted rearward in relation to the true vertical centerline of the tire viewed from the side.

Avance positivo del pivote de la rueda Es el ángulo de una línea a través del centro de la llanta que está inclinada hacia atrás en relación con la verdadera línea central vertical de la llanta vista por el lado.

Positive-phase steering Is applied to the mode when the rear wheels are steered in the same direction as the front wheels.

Guiado de fase positiva Se aplica cuando las ruedas traseras se guían en la misma dirección de las delanteras.

Positive offset Occurs when the wheel centerline is located inboard from the vertical wheel-mounting surface.

Desfasaje positivo Se produce cuando la línea central de las ruedas se encuentra dentro de la superficie vertical de montaje de las ruedas.

Positive scrub radius Occurs when the SAI line through the center of the lower ball joint and upper strut mount meets the road surface inside the true vertical centerline of the tire at the road surface as viewed from the front.

Radio matorral positivo Condición que ocurre cuando la línea SAI a través del centro de la junta esférica inferior y el montaje del montante superior entra en contacto con la superficie del camino dentro de la línea central vertical real del neumático en la superficie del camino vista desde la parte frontal.

Pre-safe systems React during the few milliseconds before a collision occurs to increase driver and passenger safety.

Presistema de protección Reacción durante los pocos milisegundos antes de que ocurra un choque para aumentar la seguridad del conductor y del pasajero

Pressure relief ball A spring-loaded ball that opens at a specific pressure and limits pressure in a hydraulic system.

Bola de alivio de presión Bola con cierre automático que se abre a una presión específica y limita la presión en un sistema hidráulico.

Programmed ride control (PRC) system A computer-controlled suspension system in which the computer operates an actuator in each strut to control strut firmness.

Sistema de control programado del viaje Sistema de suspensión controlado por computadora en el que la computadora opera un accionador en cada uno de los montantes para controlar la firmeza de los mismos.

Pulse width modulation (PWM) A method of computer control in which the computer cycles an output on and off with a variable on time.

Modulación de duración de impulsos Método de control de computadoras en el que la computadora produce un ciclo de rendimiento a intérvalos; lo que produce un trabajo efectivo variable en cada ciclo.

Pulse width modulated (PWM) voltage signal Is a signal with a variable on time that may be used by a computer to control an output.

Señal modulada de la anchura entre impulsos Es una señal con una variable de tiempo que puede usar una computadora para controlar una potencia de salida.

Puncture sealing tires A tire with a special compound on the inner tire surface that seals punctures when the puncturing object is removed from the tire.

Neumáticos autoselladores Neumático con un compuesto especial en la superficie de la parte interior que sella pinchazos cuando se le remueve el objecto punzante al neumático.

Pyrotechnic Device that contains an explosive and an ignition source.

Pirotecnia Dispositivo que contiene un explosivo y una fuente de ignición.

Quadrasteer® A type of 4WS system used on some SUVs.

Quadrasteer® Un tipo de suspensión de cuatro ruedas utilizado en algunos modelos de SUV.

Rack A horizontal shaft in a rack and pinion steering gear containing teeth that are meshed with the pinion teeth.

Cremallera Eje horizontal en un mecanismo de dirección de cremallera y piñón que contiene los dientes que se engranan con los del piñón.

Rack and pinion power steering system A type of power steering in which the steering gear contains a pinion gear that is meshed with teeth on the horizontal rack.

Sistema de dirección hidráulica de cremallera y piñón Tipo de dirección hidráulica en la que el mecanismo de dirección contiene un piñón que se engrana con los dientes de la cremallera horizontal.

Rack and pinion steering linkage A rack and pinion steering gear with the tie-rods connected from the rack ends or rack center to the steering arms.

Cuadrilátero de la dirección de cremallera y piñón Mecanismo de dirección de cremallera y piñón con las barras de acoplamiento conectadas de los extremos de la cremallera o del centro de la misma a los brazos de dirección.

Rack-drive EPS The electric motor that provides steering assist is coupled to the rack in the steering gear.

Cremallera de dirección GPE(guiado de propulsión electrónica) El motor eléctrico que proporciona ayuda de dirección acompaña a la cremallera en el mecanismo de dirección.

Rack piston A piston mounted on the rack in a power rack and pinion steering gear. Hydraulic pressure is supplied to this piston for power steering assistance.

Pistón de la cremallera Pistón montado en la cremallera en un mecanismo de dirección hidráulica de cremallera y piñón. A este pistón se le suministra presión hidráulica para reforzar la dirección hidráulica.

Rack seals Are positioned between the rack and the housing in a rack and pinion steering gear.

Juntas de estanqueidad de la cremallera Ubicadas entre la cremallera y el alojamiento en un mecanismo de dirección de cremallera y piñón.

Radial bearing load A load applied in a vertical direction.

Carga de marcación radial Carga aplicada en dirección vertical.

Radial-ply tires A tire in which the carcass plies are positioned at 90° in relation to the center of the tire, and steel or fiberglass belts are mounted under the tread.

Neumáticos de cordón radial Neumático fabricado con las estrias de armazón colocadas a un ángulo de 90° con relación al centro del neumático, y correas de acero o de fibra de vidrio montadas debajo de la huella.

Raise vehicle command A command, or signal, sent from a height sensor to the computer in a computer-controlled suspension system indicating the chassis height must be raised.

Orden para levantar el vehículo Orden o señal enviada desde un sensor de altura a la computadora en un sistema de suspensión controlado por computadora que indica que debe levantarse la altura del chasis.

Reactive Having the capability to cause a chemical reaction with another substance.

Reactivo Que tiene la capacidad de producir una reacción química con otra sustancia.

Real-time damping (RTD) system A term used to designate the road-sensing suspension system in onboard diagnostics.

Sistema de amortiguamiento en tiempo real Término utilizado para designar el sistema de suspensión con equipo sensor en pruebas de diagnóstico realizadas en el vehículo mismo.

Rear active steering (RAS) Has recently been introduced as standard equipment on the 2006 Infinity M series luxury car. The RAS makes the steering and handling characteristics on this long-wheelbase car more nimble and agile compared with models without this technology.

Dirección activa trasera (DAT) Últimamente se presentó como un equipo estándar en la serie del automóvil de lujo de la serie Infinity M del 2006. La DAT hace que la dirección y las características de manipulación de este automóvil de paso largo sean más ligeras y ágiles comparadas con los modelos que no poseen esta tecnología.

Rear-axle bearing A bearing that supports the rear axle in the housing on a rear wheel drive vehicle.

Cojinete del eje trasero Cojinete que apoya el eje trasero en el alojamiento en un vehículo de tracción trasera.

Rear axle offset A condition in which the complete rear axle assembly has turned so one rear wheel has moved forward, and the opposite rear wheel has moved rearward.

Desviación del eje trasero Condición que ocurre cuando todo el conjunto del eje trasero ha girado de manera que una de las ruedas traseras se ha movido hacia adelante y la opuesta se ha movido hacia atrás.

Rear axle sideset A condition in which the rear axle assembly has moved sideways from its original position.

Resbalamiento lateral del eje trasero Condición que ocurre cuando el conjunto del eje trasero se ha movido lateralmente desde su posición original.

Rear steering actuator An assembly that controls rear wheel steering in some four-wheel steering systems.

Accionador de la dirección trasera Conjunto que controla la dirección de la rueda trasera en algunos sistemas de dirección en las cuatro ruedas.

Rear wheel camber The tilt of a line through the rear tire and wheel centerline in relation to the true vertical centerline of the rear tire and wheel.

Comba de las ruedas traseras El ángulo de una línea que atraviesa el eje mediano del neumático trasero y de la rueda en relación al eje mediano verdadero del neumático trasero y la rueda.

Rear wheel toe The distance between the front edges of the rear wheels in relation to the distance between the rear edges of the rear wheels.

Tope de la rueda trasera Distancia entre los bordes frontales de las ruedas traseras con relación a la distancia entre los bordes traseros de las ruedas traseras.

Rebound travel Downward wheel and suspension movement.

Rebote Movimiento descendente de la rueda y de la suspensión.

Receiver An electronic device in some computer-controlled wheel aligners that receives high-frequency voltage signals from the wheel sensors.

Receptor Un dispositivo electrónico en algunos alineadores controlados por computadoras que recibe los señales de alta frequencia de los sensores de las ruedas.

Regenerative braking A system on a hybrid or electric vehicle that allows the drive wheels to turn the electric drive motor so it recharges the battery during vehicle deceleration.

Frenado regenerativo Un sistema en un vehículo híbrido o eléctrico que permite que las ruedas motrices giren el motor de impulsión eléctrica para que recargue la batería durante la desaceleración del vehículo.

Regular-duty coil spring A coil spring supplied to handle average loads to which the vehicle is subjected. This type of spring has smaller wire diameter compared with a heavy-duty spring.

Muelle helicoidal para servicio normal Muelle helicoidal provisto para sostener la carga normal a la que el vehículo está expuesto. Este tipo de muelle tiene un cable de un diámetro más pequeño comparado con un muelle para servicio pesado.

Release valve A valve that releases fluid pressure from a wheel caliper during antilock brake operation.

Válvula descargador Una válvula que descarga la presión de fluido del calíbre de la rueda durante la operación de frenado antibloqueante.

Remote reservoir A reservoir mounted separately from the power steering pump.

Depósito remoto Un depósito montado separadamente de la bomba de dirección hidráulica.

Replacement tires Tires purchased to replace the original tires that were supplied by the vehicle manufacturer.

Neumáticos de repuesto Neumáticos que se compran para reemplazar los neumáticos originales provistos por el fabricante del vehículo.

Resonance A reinforcement of sound in a vibrating body caused by sound waves from another body.

Resonancia Una fortificación del sonido en un cuerpo vibrante causada por las ondas sónicas de otro cuerpo.

Resource Conservation and Recovery Act (RCRA) States that hazardous material users are responsible for hazardous materials

from the time they become a waste until the proper waste disposal is completed.

Ley de Conservación y Recuperación de Recursos Establece que los usuarios de materiales peligrosos se encarguen de estos materiales desde el momento en que se convierten en desperdicios hasta que se lleve a cabo la eliminación adecuada de los mismos.

Road crown The higher center of a road surface in relation to the edges of this surface.

Corona de camino Centro más alto de la superficie de un camino con relación a los bordes de la misma.

Road force variation Is a condition that occurs when tire sidewalls do not have equal stiffness around the complete area of the sidewalls.

Variación de la fuerza en carretera Es una condición que sucede cuando las paredes laterales de las llantas no tienen la rigidez equitativa alrededor del área completa de las paredes laterales.

Road variables Variables such as weight in the vehicle or road surface that affect wheel alignment while driving.

Variables del camino Condiciones variables, como por ejemplo el peso en el vehículo o la superficie del camino que afectan la alineación de la rueda durante un viaje.

Rolling elements The balls or rollers and the separator in a bearing.

Elementos rodantes Las bolas o rodillos y el separador en un cojinete.

Ross cam and lever steering gear A type of steering gear used in the early 1900s that had a spiral groove in the lower end of the steering shaft meshed with a pin on the pitman shaft.

Mecanismo de dirección de leva y palanca Ross Tipo de mecanismo de dirección utilizado a principios de siglo que tenía una ranura espiral en el extremo inferior del eje de dirección engranado con un pasador en el árbol pitman.

Rotary valve A valve mounted with the spool valve in a power steering gear. The position of these two valves directs power steering fluid to the appropriate side of the rack or power piston.

Válvula rotativa Válvula montada con la válvula de carrete en un mecansimo de dirección hidráulica. La posición de estas dos válvulas dirige el fluido de la dirección hidráulica al lado apropiado de la cremallera o del pistón impulsor.

Run-flat tires Tires designed to operate safely without any air pressure for a specific distance.

Neumáticos de no presión Los neumáticos diseñados a operar sin peligro sín presión por distancias específicas.

Safety and gateway module (SGM) Operates the servotronic valve and the electronically controlled orifice valve in some power steering systems.

Módulo de puerta de enlace y seguridad (SGM, en inglés) Opera la válvula servotrónica y la válvula de orifi cio controlado electrónicamente en algunos sistemas de dirección de potencia.

Scrub radius The distance between the SAI line and the true vertical centerline of the tire at the road surface.

Radio matorral Distancia entre la línea SAI y la línea central vertical real del neumático en la superficie del camino.

Sector A shaft in a recirculating ball steering gear that is connected to the pitman shaft. The gear teeth on the sector shaft are meshed with the worm gear.

Sector Árbol en un mecanismo de dirección con bola recirculante que se conecta al árbol pitman. Los dientes del engranaje en el eje sector se endentan con el engranaje sinfín.

Semi-independent rear suspension A rear suspension system in which one rear wheel has a limited amount of movement without affecting the opposite rear wheel.

Suspensión trasera semi-independiente Sistema de suspensión trasera en el que una de las ruedas traseras tiene una cantidad limitada de movimiento sin afectar la rueda trasera opuesta.

Separator A component that prevents contact between two other parts.

Separador Componente que evita que otras dos piezas entren en contacto.

Series HEVs A hybrid electric vehicle in which the internal combustion engine and the electric drive motor both supply torque to the drive wheels.

HEV de serie Un vehículo híbrido eléctrico en el cual tanto el motor de combustión interna como el motor de impulsión eléctrica proporcionan potencia a las ruedas motrices.

Serpentine belt A ribbed V-belt drive system in which all the belt-driven components are on the same vertical plane.

Correa serpentina Sistema de transmisión con correa nervada en V en el que todos los componentes accionados por una correa se encuentran sobre el mismo plano vertical.

Servotronic valve A computer-controlled valve in an active steering system that controls power steering pump pressure in relation to vehicle speed.

Válvula servotrónica Una válvula controlada por computadora en un sistema de dirección activo que controla la presión de la bomba de dirección de potencia de acuerdo con la velocidad del vehículo.

Shock absorber A hydraulic mechanism connected between the chassis and the suspension to control spring action.

Amortiguador Un mecanismo hidráulico conectado entre el chasis y la suspensión para controlar la acción del muelle.

Shock absorber ratio The amount of extension control compared with the amount of compression control.

Relación del amortiguador Cantidad de control de extensión comparado con la cantidad de control de compresión.

Short-and-long arm front suspension systems Suspension systems in which the upper control arm is shorter than the lower control arm.

Sistemas de suspensión de brazos largos y cortos Un sistema suspensión en el cual el brazo de control superior es más corto que el brazo de control inferior.

Sideslip The tendency of the rear wheels to slip sideways because of centrifugal force while a vehicle is cornering at high speed.

Patinaje Tendencia de las ruedas traseras a deslizarse lateralmente a causa de la fuerza centrífuga mientras un vehículo hace un viraje a gran velocidad.

Side sway Occurs when one side of a vehicle frame is bent inward.

Desviación Ocurre cuando un lado del bastidor del vehículo esta torcido hacia adentro.

Sidewall The area between the tread and the bead of a tire.

Pared lateral Área entre la huella y la pestaña de un neumático.

Silencer A component designed to reduce noise.

Silenciador Componente diseñado para disminuir el ruido.

Single-row ball bearing A bearing with a single row of balls.

Cojinete de bola de una sola fila Cojinete que contiene una sola fila de bolas.

Slip angle The actual angle of the front wheels during a turn compared with the turning angle of the front wheels with the vehicle at rest.

Ángulo de patinaje Ángulo real de las ruedas delanteras durante un viraje comparado con el ángulo de giro de las ruedas delanteras cuando se ha detenido la marcha del vehículo.

Snapring A circular steel ring with some tension designed to snap into a groove and retain a component.

Anillo de resorte Anillo circular de acero con un poco de tensión diseñado para ajustarse dentro de una ranura y sujetar un componente en su posición.

Society of Automotive Engineers (SAE) A society of professional engineers that provides many member and industry services, such as the development of industry standards and the communication of engineering information through publications and conferences.

Sociedad de Ingenieros de Automóviles (SAE) Sociedad de ingenieros profesionales que les provee muchos servicios a sus miembros y a la industria, como por ejemplo, el desarrollo de normas para la industria, y la comunicación de información sobre ingeniería mediante publicaciones y conferencias.

Sodium-based grease A special lubricant with a sodium base that may be required on some steering components.

Grasa a base de sodio Lubricante especial con una base de sodio que podrían necesitar algunos componentes de la dirección.

Soft relay A relay in a computer-controlled suspension system that supplies voltage to the strut actuators in the soft mode.

Relé blando Un relé en un sistema de suspensión controlado por computadora que suministra el voltaje a los accionadores de los montantes en un modo blando.

Speed rating A tire rating that indicates the maximum safe vehicle speed that a tire will withstand.

Clasificación de la velocidad Clasificación de un neumático que indica la velocidad máxima que podrá resistir un neumático.

Speed sensitive steering (SSS) system A computer-controlled steering system that varies the steering effort in relation to vehicle speed.

Dirección sensible a la velocidad Sistema de dirección controlado por computadora que varía el esfuerzo necesario de la dirección de acuerdo a la velocidad del vehículo.

Spherical bearing A bearing shaped like a sphere and used in some tilt steering wheels.

Cojinete esférico Cojinete en forma de esfera utilizado en algunos volantes de dirección inclinables.

Spiral cable A conductive ribbon that is mounted in a plastic container on top of the steering column and maintains electrical contact between the air bag inflator module and the air bag electrical system. A spiral cable may be called a clock spring electrical connector.

Cable espiral Cinta conductiva montada en un recipiente plástico sobre la columna de dirección que mantiene el contacto eléctrico entre la unidad infladora y el sistema eléctrico del Airbag. El cable espiral se conoce también como conector eléctrico de cuerda de reloj.

Spool valve Positioned with the rotary valve in a power steering gear. These two valves direct power steering fluid to the appropriate side of the rack or power piston to provide steering assistance.

Válvula de carrete Ubicada con la válvula rotativa en un mecanismo de dirección hidráulica. Estas dos válvulas dirigen el fluido de la dirección hidráulica al lado apropiado de la cremallera o del pistón impulsor para reforzar la dirección.

Spring insulator Positioned between the ends of a coil spring and the spring mounting surfaces to reduce the transfer of noise and vibration from the spring to the chassis.

Aisladore de muelle Ubicados entre los extremos de un muelle helicoidal y las superficies para el montaje de muelles con el propósito de reducir la transferencia de ruido y la vibración del muelle al chasis.

Springless seal A seal lip with no spring behind the lip.

Junta de estanqueidad sin muelle Reborde de una junta de estanqueidad que no tiene un muelle detrás del mismo.

Spring-loaded seal A seal lip with a garter spring behind the lip to increase lip tension.

Junta de estanqueidad con cierre automático Reborde de una junta de estanqueidad con un muelle jarretera detrás del reborde para aumentar la tensión del mismo.

Sprung weight Is the vehicle weight that is supported by the coil springs.

Peso suspendido Es el peso del vehículo que soportan los muelles en espiral cilíndrica.

Spur gear teeth Gear teeth that are parallel to the centerline of the gear.

Dientes de engranaje rectos Dientes del engranaje que son paralelos a la línea central del engranaje.

Stabilitrak® A computer-controlled system that provides vehicle stability control by reducing sideways swerving.

Stabilitrak® Un sistema controlado por computadora que provee el control de estabilidad del vehículo asi disminuyendo viraje lateral.

Static balance Refers to the balance of a tire and wheel at rest.

Equilibrio estático Se refiere al equilirio de un neumático y una rueda cuando se ha detenido la marcha del vehículo.

Steering angle The angle of the front wheel on the inside of a turn compared to the angle of the front wheel on the outside of the turn.

Ángulo de la dirección Ángulo de la rueda delantera en el interior de un viraje comparado con el ángulo de la rueda delantera en el exterior del viraje.

Steering angle sensor An optical-type sensor that supplies a voltage signal in relation to steering wheel rotation.

Sensor del ángulo de la dirección Un sensor de tipo óptico que proporciona una señal de voltaje de acuerdo con la rotación del volante

Steering axis inclination (SAI) The angle of a line through the center of the upper strut mount and lower ball joint in relation to the true vertical centerline of the tire viewed from the front of the vehicle.

Inclinación del pivote de dirección Ángulo de una línea a través del centro del montaje del montante superior y la junta esférica inferior con relación a la línea central vertical real del neumático vista desde la parte frontal del vehículo.

Steer-by-wire A computer-controlled steering system with no direct mechanical connection between the steering wheel and the steering gear.

Dirección alámbrica Un sistema de dirección controlado por computadora sín una conexión mecánica directa entre el volante de dirección y el aparato de dirección.

Steering gear free play The amount of steering wheel movement before the front wheels begin to turn.

Juego en el aparato de dirección Cantidad de movimiento del volante de dirección antes de que las ruedas delanteras comiencen a girar.

Steering drift The tendency of the steering to drift slowly to one side when the vehicle is driven straight ahead on a smooth, straight road surface.

Desviación de la dirección La tendencia de la dirección a desviarse poco a poco hacia un lado mientras que el vehículo se conduce en línea recta sobre un camino liso y nivelado.

Steering kickback Road force supplied back to the steering wheel.

Tensión de retroceso de la dirección Fuerza del camino que se vuelve a suministrar al volante. Sensor de posició

Steering pull The tendency of the steering to pull constantly to one side or the other when driving the vehicle straight ahead on a smooth, level road surface.

Tiro en la dirección La tendencia de la dirección a tirar en una manera constante hacia un lado u otro mientras que el vehículo se conduce en línea recta sobre un camino liso y nivelado.

Steering ratio The number of degrees of steering wheel rotation in relation to the number of degrees of front wheel movement.

Relación de la dirección Número de grados de rotación del volante de dirección con relación al número de grados de movimiento de la rueda delantera.

Steering sensor A sensor that sends a voltage signal to the computer in relation to the amount and speed of steering wheel rotation in a programmed ride control (PRC) system.

Sensor de dirección Un sensor que manda una señal de voltaje a la computadora en relación a la cantidad y la velocidad de la rotación del volante de dirección en un sistema de viaje controlado (PRC).

Steering wander The tendency of the steering to pull to the right or left when the vehicle is driven straight ahead on a smooth road surface.

Desviación de la dirección Tendencia de la dirección a desviarse hacia la derecha o hacia la izquierda cuando se conduce el vehículo en línea recta en un camino cuya superficie es lisa.

Steering wheel angle sensor (SWAS) Provides a voltage signal on relation to steering wheel rotation.

Sensor del ángulo del volante (SWAS, en inglés) Proporciona una señal de voltaje de acuerdo con la rotación del volante.

Steering wheel position sensor (SWPS) A sensor that produces a voltage signal in relation to the amount and velocity of steering wheel rotation.

Sensor de posición de la dirección (SWPS) Un sensor que produce una señal de voltaje en relación a la cantidad y la velocidad de rotación del volante de dirección.

Steering wheel rotation sensor An input sensor in a computer-controlled suspension or steering system that sends a signal to the computer in relation to the amount and speed of steering wheel rotation.

Sensor de la rotación del volante de dirección Sensor de entrada en un sistema de suspensión controlado por computadora o en un sistema de dirección que le envía una señal a la computadora referente a la cantidad y a la velocidad de la rotación del volante de dirección.

Stop-to-stop Steering wheel rotation from extreme left to extreme right.

Parada a parada Rotación del volante de dirección desde la extrema izquierda hasta la extrema derecha.

Struts Components connected from the top of the steering knuckle to the upper strut mount that maintain the knuckle position and act as shock absorbers to control spring action.

Montantes Componentes conectados de la parte superior del muñón de dirección al montaje del montante superior que mantienen la posición del muñón y actúan como amortiguadores para controlar el movimiento de ascenso y descenso del muelle.

Summation sensor Provides a voltage signal in relation to steering rack position.

Sensor de suma Proporciona una señal de voltaje de acuerdo con la posición del soporte de la dirección.

Synthetic rubber A type of rubber developed in a laboratory.

Caucho sintético Tipo de caucho fabricado en un laboratorio.

Tapered roller bearing A bearing containing tapered roller bearings mounted between the inner and outer races.

Cojinete de rodillos cónicos Cojinete que contiene cojinetes de rodillos cónicos montados entre los anillos interiores y exteriores.

Taper-wire closed-end springs Coil spring ends that are tapered to a smaller diameter.

Muelles helicoidales de extremos cónicos Extremos de muelles helicoidales a los que se les da forma de cono para reducir su diámetro.

Telematics Using an in-vehicle phone for communication, with the vehicle driver regarding vehicle diagnostics, emissions, or traffic- and safety-related concerns.

Telemática Uso de un teléfono incorporado al vehículo para comunicarse con el conductor del vehículo acerca de problemas de diagnóstico, emisiones, tránsito y seguridad.

Temperature rating A tire rating that indicates the ability of the tire to withstand heat.

Clasificación de la temperatura Clasificación de un neumático que indica la capacidad del neumático de resistir el calor.

Tension loaded A ball joint mounted so the vehicle weight tends to pull the ball out of the joint.

Cargada de tensión Junta esférica montada de manera que el peso del vehículo tiende a remover la bola de la junta.

Throttle position sensor (TPS) Sends an analog voltage signal to the engine computer in relation to throttle opening.

Sensor de posición del acelerador (TPS, en inglés) Envía una señal de voltaje analógica a la computadora del motor en relación con la apertura del acelerador.

Thrust angle The angle between the thrust line and the vertical centerline of the vehicle.

Ángulo de empuje El ángulo entre la línea de empuje y el eje mediano vertical del vehículo.

Thrust bearing load This type of load may be called an axial load.

Carga del cojinete de empuje Este tipo de carga puede llamarse una carga.

Thrust line An imaginary line positioned at a 90° angle to the center of the rear axle and extending forward.

Directriz de presiones Una línea imaginaria en posición de un ángulo de 90° con relación al centro del eje trasero y que se extiende hacia enfrente.

Thrust line alignment A wheel alignment in which the thrust line is used as a reference for front wheel toe adjustment.

Alineación de la línea de empuje Alineación de la rueda en la que se utiliza la línea de empuje como punto de referencia para el ajuste del tope de la rueda delantera.

Tie-rod A rod connected from the steering arm to the rack or center link, depending on the type of steering linkage.

Barra de acoplamiento Varilla conectada del brazo de dirección a la cremallera o a la biela motriz central, dependiendo del tipo de cuadrilátero de la dirección.

Tire belts Belts that are placed under the tire tread to provide longer tread wear. Belts are usually made from steel or polyester.

Banda de refuerzo del neumático Las bandas que se colocan debajo de la banda de rodamiento para aumentar la durabilidad de la banda de rodamiento. Las bandas suelen ser fabricadas del acero o del poliester.

Tire chains May be placed over the tires to improve traction when driving on ice or snow.

Cadenas antideslizantes Pueden colocarse sobre los neumáticos para mejorar la tracción cuando se conduce el vehículo en el hielo o la nieve.

Tire contact area The part of the tire in contact with the road surface when the tire is supporting the vehicle weight.

Área de contacto del neumático Parte del neumático en contacto con la superficie del camino cuando el neumático apoya el peso del vehículo.

Tire free diameter The distance between the outer edges of the tread measured on a horizontal line through the center of the wheel.

Diámetro libre del neumático Distancia entre los bordes exteriores de la huella que se mide sobre una línea horizontal a través del centro de la rueda.

Tire performance criteria (TPC) Information molded on the tire sidewall indicating that the tire meets the manufacturer's performance standards for traction, endurance, dimensions, noise, handling, and rolling resistance.

Criterio sobre el rendimiento del neumático Información moldeada en la pared lateral del neumático que indica que el neumático cumple con las normas de rendimiento establecidas por el fabricante sobre la tracción, acción, dimensiones, ruido, movilización, y resistencia al rodaje.

Tire placard Often attached to the rear face of the driver's door, the tire placard provides information regarding maximum vehicle load, tire size, and cold inflation pressure.

Cartel del neumático Comúnmente fijado a la cara posterior de la puerta del conductor, el cartel del neumático provee información referente a la carga máxima del vehículo, el tamaño del neumático, y la presión fría de inflación.

Tire pressure The amount of air pressure contained in the tire to allow the tire to carry a load.

Presión del neumático La cantidad del presión de aire contenido en el neumático para permitir que el neumático soporta una carga.

Tire rolling diameter The distance between the outer edges of the tread measured on a vertical line through the center of the wheel when the tire is supporting the vehicle weight.

Diámetro del rodaje del neumático Distancia entre los bordes exteriores de la huella que se mide sobre una línea vertical a través del centro de la rueda cuando el neumático apoya el peso del vehículo.

Tire treads The part of the tire in contact with road surface.

Bandas de rodamiento del neumático La parte del neumático que se pone en contacto con la superficie del camino.

Tire valves Mounted in the wheel rim, the tire valves allow air to enter or be exhausted from the tire.

Válvulas del neumático Estas válvulas están montadas en la llanta de la rueda y permiten la entrada o la salida de aire desde el neumático.

Toe-in A condition that is present when the distance between the front edges of the front or rear wheels is less than the distance between the rear edges of the wheels.

Convergencia Condición que ocurre cuando la distancia entre los bordes frontales de las ruedas delanteras o traseras es menor que la distancia entre los bordes traseros de las mismas.

Toe-out A condition that is present when the distance between the front edges of the front or rear wheels is more than the distance between the rear edges of the wheels.

Divergencia Condición que ocurre cuando la distancia entre los bordes delanteros de las ruedas delanteras o traseras es mayor que la distancia entre los bordes traseros de las mismas.

Toe-out on turns The steering angle of the wheel on the inside of a turn compared with the steering angle of the wheel on the outside of the turn.

Divergencia durante un viraje El ángulo de la dirección de la rueda en el interior de un viraje comparado con el ángulo de la dirección de la rueda en el exterior del viraje.

Toe plate A metal plate surrounding the steering column and attached to the vehicle floor.

Placa de pie Una placa de metal que rodea la columna de dirección y conectada al piso del vehículo.

Torque A twisting force.

Par de torsión Fuerza de torcimiento.

Torque steer The tendency of the steering on a front-wheel-drive vehicle with unequal drive axles to pull to one side during hard acceleration.

Dirección de torsión Tendencia de la dirección en un vehículo de tracción delantera con ejes de mando desiguales a desviarse hacia un lado durante una aceleración rápida.

Torsion bar A steel bar connected from the chassis to the lower control arm. As the vehicle weight pushes the chassis downward, the torsion bar twists to support this weight. Torsion bars are used in place of coil springs.

Barra de torsión Barra de acero conectada del chasis al brazo de mando inferior. Mientras el peso del vehículo presiona el chasis hacia abajo, la barra de torsión se tuerce para apoyar este peso. Las barras de torsión se utilizan en lugar de los muelles helicoidales.

Tracking Refers to the position of the rear wheels in relation to the front wheels.

Encarrilamiento Se refiere a la posición de las ruedas traseras con relación a las ruedas delanteras.

Traction control system (TCS) A computer-controlled system that prevents drive wheel spinning.

Sistema de control de tracción (TCS) Un sistema controlado por computador que previene que giran las ruedas de propulsión.

Traction rating A tire rating indicating the traction capabilities of the tire.

Clasificación de tracción Clasificación de un neumático que indica las capacidades de tracción del mismo.

Transitional coils Coils located between the inactive and active coils in variable rate coil springs.

Bobinas de transición Las bobinas localizadas entre las bobinas inactivas y activas en los resortes helicoidales de relación variable.

Transistors Fast-acting electronic switches with no moving parts.

Transistores Interuptores electrónicas de acción rápida sín partes móviles.

Travel-sensitive strut A strut with the capability to adjust its firmness in relation to the amount of piston travel inside the strut.

Montante sensible al movimiento Montante con la capacidad de ajustar su firmeza de acuerdo a la cantidad de movimiento del pistón dentro del montante.

Tread wear rating A tire rating indicating the wear capabilities of the tread that allow customers to compare tire life expectancy.

Clasificación del desgaste de un neumático Clasificación de un neumático que indica las capacidades de desgaste de la huella y le permite a los clientes comparar el índice de durabilidad del neumático.

Trim height The specified, or normal, suspension height in a computer-controlled suspension system.

Altura de la suspensión Altura especificada, o normal, de la suspensión en un sistema de suspensión controlado por computadora.

Tubular frame A frame member with a circular, or tubular, design.

Fabricación del armazón en forma tubular Pieza del armazón diseñada en forma circular o tubular.

Turning circle The turning angle of one front wheel in relation to the opposite front wheel during a turn.

Círculo de giro Ángulo de giro de una de las ruedas delanteras con relación a la rueda delantera opuesta durante un viraje.

Turning radius The turning angles of the front wheels around a common center point.

Diámetro del giro Los ángulos de giro de las ruedas frontales alrededor de un punto central común.

Uniform Tire Quality Grading (UTQG) System Information including tread wear, traction, and temperature ratings that is molded into the tire sidewall, and is required by the Department of Transportation (DOT).

Sistema de sobre la clasificación de la calidad uniforme de neumáticos Información moldeada en la pared lateral del neumático que incluye el desgaste de la huella, la tracción, y las clasificaciones de temperatura y que es requerida por el Ministerio de Transporte.

Unitized body A body design that does not have a frame because each body component is a supporting member.

Carrocería unificada Diseño de la carrocería que no tiene armazón porque cada uno de sus componentes es una pieza suplementaria.

Unsprung weight Is the vehicle weight that is not supported by the coil springs.

Peso no suspendido Es el peso del vehículo que no soportan los muelles en espiral cilíndrica.

Upper strut mount A mount connected between the strut and the strut tower. Front upper strut mounts contain a bearing that allows strut rotation.

Montaje de los montantes superiores Montaje conectado entre el montante y la torre del montante. Los montajes frontales y superiores contienen un cojinete que permite la rotación del montante.

Vacuum A pressure that is less than atmospheric pressure.

Vacío Presión menor que la de la atmósfera.

Vane-type power steering pumps Pumps that have rotors with metal vanes that provide a seal between the rotor and the pump cam.

Bombas de dirección hidráulica tipo aletas Las bombas que tienen rotores con aletas de metal que proveen un sello entre el rotor y la leva de la bomba.

Variable effort steering (VES) A computer-controlled steering system that provides reduced steering effort at low vehicle speeds and increased steering effort at higher vehicle speeds.

Dirección de esfuerzo variable Sistema de dirección controlado por computadora que provee un menor esfuerzo de dirección cuando el vehículo viaja a velocidad baja y un mayor esfuerzo de dirección cuando el vehículo viaja a gran velocidad.

Variable-rate coil springs Rather than having a standard spring deflection rate, these springs have an average spring rate based on load at a predetermined deflection.

Muelles helicodal de capacidad variable En vez de tener una capacidad de desviación de muelle estándar, estos muelles tienen un valor promedio de elasticidad basado en la carga a una desviación predeterminada.

V-belt A drive belt with a V-shape.

Correa en V Correa de transmisión en forma de V.

Vehicle dynamic suspension (VDS) System found in some SUVs that is similar to air suspension systems.

Suspensión dinámica del vehículo (SDV) Sistema que se encuentra en algunas camionetas SUV que es similar a los sistemas de suspensión de aire.

Vehicle speed sensor (VSS) An input sensor that sends a voltage signal to the engine computer in relation to vehicle speed.

Sensor de la velocidad del vehículo Sensor de entrada que le envía una señal de tensión a la computadora del motor referente a la velocidad del vehículo.

Vehicle stability control system A computer-controlled system that prevents vehicle swerving, especially during hard acceleration on slippery road surfaces.

Sistema de control de estabilidad del vehículo Un sistema controlado por computadora que previene que se desvía el vehículo, especialmente durante una aceleración fuerte sobre un camino cuyo superficie es resbalosa.

Vehicle wander The tendency of the steering to pull to the left or right when the vehicle is driven straight ahead on a smooth road surface.

Desviación de la marcha del vehículo Tendencia de la dirección a desviarse hacia la izquierda o hacia la derecha cuando se conduce el vehículo en línea recta en un camino cuya superficie es lisa.

Vent valve An electrically operated valve that vents air from an air spring in a computer-controlled suspension system.

Válvula de respiración Válvula activada eléctricamente que da salida al aire desde un muelle de aire en un sistema de suspensión controlado por computadora.

Venturi A narrow portion of an air passage.

Venturi Una porción estrecha de un pasaje de aire.

Vibration A rapid motion of particles, or a component that produces sound.

Vibración Un movimiento rápido de los partículos, o de un componente que produce un sonido.

Volume Volume is the length, width, and height of the space occupied by an object.

Volumen El volumen es la longitud, la anchura y la altura del espacio ocupado por un objeto.

Watts rod A rod connected from the chassis to the rear suspension to reduce body side sway, usually referred to as a tracking bar.

Barra wats Una barra conectada del chasis a la suspensión trasera para disminuir la oscilación lateral de la carrocería, suele referirse como una barra de tracción.

Wear indicators Rubber bars located near the bottom of tire treads. When the tread is worn to a specific depth, these bars become visible.

Indicadores del desgaste Las barras del caucho localizadas cerca la parte inferior de las bandas de rodamiento de los neumáticos. Cuando las bandas de rodamiento se han gastado a una profundidad específica, estas barras son visibles.

Weight The measurement of the earth's gravitational pull on an object.

Peso La medida de la atracción gravitacional de la tierra en un objeto.

Wheel alignment May be defined as an adjustment and refitting of suspension parts to original specifications that ensures design performance.

Alineación de una rueda Puede definirse como un ajuste y una reparación de las piezas de la suspensión según las especificaciones originales, lo que asegura el rendimiento del diseño.

Wheelbase The distance between the center of the front and rear wheels.

Distancia entre ejes Distancia entre el centro de las ruedas delanteras y traseras.

Wheel offset The distance between the vertical wheel-mounting surface and the centerline of the wheel.

Desfasaje de rueda La distancia entre la superficie vertical de montaje de ruedas y la línea central de la rueda.

Wheel position sensor Is connected between each front and rear lower control arm and the chassis in a road-sensing suspension system. This sensor provides a computer input signal in relation to the amount and velocity of wheel movement.

Sensor para la posición de las ruedas Se conecta entre cada uno de los brazos de mando delantero y trasero y el chasis en un sistema de suspensión con equipo sensor. Este sensor envía una señal de entrada a la computadora referente a la cantidad y la velocidad del movimiento de la rueda.

Wheel rims Circular steel, aluminum, or magnesium components on which the tires are mounted. The wheel rim and tire assembly is bolted to the wheel hub.

Llantas de la rueda Componentes circulares de acero, aluminio o magnesio sobre los que se montan los neumáticos. El conjunto de la llanta de la rueda y el neumático se emperna al cubo de la rueda.

Wheel sensor An electronic unit attached to each wheel and connected to a four-wheel aligner.

Sensor de la rueda Una unedad electrónica prendida a cada rueda y conectada a un alineador de cuatro ruedas.

Wheel setback Occurs when one front or rear wheel is moved rearward in relation to the opposite front or rear wheel.

Retroceso de la rueda Ocurre cuando una rueda delantera o trasera se mueve hacia atrás con relación a la rueda delantera o trasera opuesta.

Wheel shimmy Rapid inward and outward oscillations of the front wheels.

Bailoteo de la rueda Oscilaciones rápidas hacia adentro y hacia afuera de las ruedas delanteras.

Wheel speed sensor Sends an AC voltage signal to the antilock brake system computer in relation to wheel speed.

Sensor de velocidad de la rueda Manda una señal de voltaje de corriente alterna a la computadora del sistema de freno antibloqueo en relación a la velocidad de la rueda.

Wheel tramp Rapid upward and downward wheel and tire movement.

Recorrido de la rueda Movimiento rápido ascendente y descendente de la rueda y el neumático.

Work The result of applying a force.

Trabajo Resultado de la aplicación de una fuerza.

Worm and gear or worm and sector design A steering gear developed in the early 1900s that required high steering effort because of internal friction.

Diseño del sinfín y engranaje o del sinfín y sector Un engranaje de dirección desarrollado en los principios de los años 1900 que requerían un gran esfuerzo en maniobro de dirección debido a la fricción interna.

Worm and roller steering gear A gear that contains a wormshaft and a roller-type sector.

Engranaje de dirección con sinfín y rodillo Un engranaje que contiene un eje de sinfín y un sector tipo rodillo.

Worm shaft The gear meshed with the pitman shaft sector in a recirculating ball steering gear.

Árbol del sinfín Engranaje endentado con el sector del árbol pitman en un mecanismo de dirección de bola recirculante.

Worm shaft bearing preload The amount of tension placed on the bearing by the adjustment procedure.

Carga previa del cojinete del árbol del sinfin Cantidad de tensión aplicada al cojinete por el procedimiento de ajuste.

Worm shaft endplay The distance between the fully upward and fully downward worm shaft positions in a recirculating ball steering gear.

Holgadura del árbol del sinfín Distancia entre las posiciones completamente ascendente y descendente del árbol del sinfín en un mecanismo de dirección de bola recirculante.

Yaw forces Tend to cause the rear of the vehicle to swerve sideways.

Fuerzas de dirección tienden a causar que la parte posterior del vehículo viren bruscamente hacia los lados.

Yaw motion The tendency of the rear of a vehicle to swerve sideways during a turn.

Movimiento de derrape La tendencia de la parte posterior de un vehículo de desplazarse lateralmente durante un giro.

Yaw rate sensor Sends a voltage signal to the vehicle stability control computer in relation to sideways chassis movement.

Sensor de cantidad de desviación Manda una señal de voltaje a la computadora de control de estabilidad del vehículo en relación del movimiento lateral del chasis.

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Glossary
Glosario

Accidental air bag deployment An unintended air bag deployment caused by improper service procedures.

Despliegue accidental del Airbag Despliegue imprevisto del Airbag ocasionado por procedimientos de reparación inadecuados.

Active roll stabilization (ARS) ECU A computer that receives input signals and controls output functions in an ARS system.

ECU de estabilización de rodamiento activo (ARS, en inglés) Una computadora que recibe señales de entrada y controla las funciones de salida en un sistema ARS.

Active steering ECU A computer that receives input signals and controls output functions in an active steering system.

ECU de dirección activa Una computadora que recibe señales de entrada y controla las funciones de salida en un sistema de dirección activa.

Advanced vehicle handling (AVH) Computer software on CD that allows the technician to locate the cause of hidden suspension, body, and chassis problems.

Manejo avanzado de vehículos (AVH, en inglés) Programa de software en CD que permite que el técnico localice la causa de problemas ocultos de suspensión, carrocería y chasis.

Air bag deployment module The air bag and deployment canister assembly that is mounted in the steering wheel for the driver's side air bag, or in the dash panel for the passenger's side air bag.

Unidad de despliegue del air bag El conjunto del Airbag y elemento de despliegue montado en el volante de dirección para proteger al conductor, o en el tablero de instrumentos para proteger al pasajero.

Air bag system Is designed to protect the driver and/or passengers in a vehicle collision.

Sistema de bolsa de aire Se diseñó para proteger al conductor y/o a los pasajeros en caso de un choque.

Alignment ramp A metal ramp positioned on the shop floor on which vehicles are placed during wheel alignment procedures.

Rampa de alineación Rampa de metal ubicada en el suelo del taller de reparación de automóviles sobre la que se colocan los vehículos durante los procedimientos de alineación de ruedas.

Antilock brake system (ABS) A computer-controlled system that prevents wheel lockup during brake applications.

Sistema de frenado antibloqueo (ABS) Un sistema controlado por computadora que previene el bloqueo de las ruedas durante la aplicación de los frenos.

Antitheft locking wheel covers Locking wheel covers that help to prevent wheel theft.

Cubrerruedas anti-robo Cubrerruedas autobloqueantes que ayudan a evitar el robo de las ruedas.

Antitheft wheel nuts Special wheel nuts designed to prevent wheel and tire theft.

Tuercas antirrobo de fijación de las ruedas Tuercas especiales de fijación de las ruedas diseñadas para evitar el robo de las ruedas y los neumáticos.

Approved gasoline storage can A special gasoline container that meets safety requirements.

Bidón aprobado para almacenamiento de gasolina Un recipiente especial para gasolina que cumple los requisitos de seguridad.

Aqueous parts cleaning tank Uses a water-based, environmentally friendly cleaning solution, such as Greasoff® 2, rather than traditional solvents.

Tanque de limpieza de partes acuosas Usa una solución a base de agua y compatible con el medio ambiente, tal como Greasoff® 2, en lugar delos solventes tradicionales.

ASE blue seal of excellence An ASE logo displayed by automotive service shops that employ ASE-certified technicians.

Sello azul de excelencia de la ASE Logotipo exhibido en talleres de reparación de automóviles donde se emplean mecánicos certificados por la ASE.

Axle offset A condition where the complete rear axle assembly has turned so one rear wheel has moved forward, and the opposite rear wheel has moved rearward.

Eje descentrado Una condición en la cual la asamblea total del eje trasero se ha girado para que una rueda se ha movido hacia afrente, y la rueda opuesta trasera se ha movido hacia atrás.

Axle pullers Are usually slide-hammer type. These pullers attach to the axle studs to remove the axle.

Extractores del eje Son generalmente de tipo martillo de corredera. Estos extractores se vinculan a los espárragos roscados del eje para quitarlo.

Backup power supply A voltage source, usually located in the air bag computer, that is used to deploy an air bag if the battery cables are disconnected in a collision.

Alimentación de reserva Fuente de tensión, por lo general localizada en la computadora del Airbag, que se utiliza para desplegar el Airbag si se desconectan los cables de la batería a consecuencia de una colisión.

Ball joint radial measurement Vertical movement in a ball joint because of internal joint wear.

Medida de radial de la junta esférica Movimiento horizontal en una junta esférica ocasionado por el desgaste interno de la misma.

Ball joint removal and installation tools Special tools required for ball joint removal and replacement.

Herramientas para la remoción y el ajuste de la junta esférica Herramientas especiales requeridas para la remoción y el reemplazo de la junta esférica.

Ball joint vertical movement Vertical movement in a ball joint because of internal joint wear.

Movimiento vertical de la junta esférica Un movimiento vertical en la junta esférica debido al desgaste interior de la junta.

Ball joint wear indicator A visual method of checking ball joint wear.

Indicador de desgaste de la junta esférica Método visual de revisar el desgaste interior de una junta esférica.

Bearing brinelling Straight line indentations on the races and rollers.

Acción de Brinnell en un cojinete Hendiduras en línea recta en los anillos y los rodillos.

Bearing fatigue spalling Flaking of the surface metal on the rollers and races.

Escamación y fatiga del cojinete Condición que ocurre cuando el metal de la superficie de los rodillos y los anillos comienza a escamarse.

Bearing frettage A fine, corrosive wear pattern around the races and rollers, with a circular pattern on the races.

Cinceladura del cojinete Desgaste corrosivo y fino alrededor de los anillos y los rodillos que se hace evidente a través de figuras circulares en los anillos.

Bearing indentations Surface indentations on races and rollers caused by hard, foreign particles.

Depresiones del cojinete Las depresiones en la superficie de los anillos y los rodillos causadas por las partículas duras foraneas.

Bearing preload A tension placed on the bearing rollers and races by an adjustment or assembly procedure.

Carga previa del cojinete Tensión aplicada a los rodillos y los anillos del cojinete a través de un procedimiento de ajuste o de montaje.

Bearing pullers Special tools designed for bearing removal.

Extractores de cojinetes Herramientas especiales diseñadas para la remoción del cojinete.

Bearing smears Metal loss from the races and rollers in a circular, blotched pattern.

Ralladuras en los cojinetes Pérdida del metal de los anillos y los rodillos que se hace evidente a través de una figura circular oxidada.

Bellows boots Accordion-style boots that provide a seal between the tie rods and the housing on a rack and pinion steering gear.

Botas de fuelles Botas en forma de acordeón que proveen una junta de estanqueidad entre las barras de acoplamiento y el alojamiento en un mecanismo de dirección de cremallera y piñón.

Belt tension gauge A special gauge used to measure drive belt tension.

Calibrador de tensión de la correa de transmisión Calibrador especial que se utiliza para medir la tensión de una correa de transmisión.

Body sway Excessive body movement from side to side.

Oscilación de la carrocería Movimiento lateral excesivo de la carrocería.

Bounce test A shock absorber test in which weight is applied to, and released from, the vehicle bumper.

Prueba de rebote Una prueba de los amortiguadores en la cual se aplica y se quita un peso en el parachoques del vehículo.

Brake parts washer A parts washer designed to wash brake parts without releasing asbestos dust into the atmosphere.

Lavador de partes de freno Un lavador de partes diseñada a lavarlas partes de freno sín dejar escapar el polvo de amianta al medio ambiente.

Brake pedal depressor A special tool installed between the front seat and the brake pedal to apply the brakes during certain wheel alignment measurements.

Depresor del pedal de frenos Una herramienta especial instalada entre el asiento de afrente y el pedal de frenos para aplicar los frenos durante ciertas medidas de alineación de las ruedas.

Brake pedal jack A special tool installed between the front seat and the brake pedal to apply the brakes during certain wheel alignment measurements.

Gato del pedal de freno Herramienta especial instalada entre el asiento delantero y el pedal de freno que se utiliza para aplicar los frenos durante ciertas medidas de alineación de ruedas.

Brake pressure modulator valve (BPMV) An assembly containing a group of solenoid valves that control brake fluid pressure during antilock brake, traction control, and vehicle stability control functions.

Válvula modulador de presión del freno (BPMV) Una asamblea que contiene un grupo de válvulas de solenoide que controlan la presión del fluido de freno durante las funciones de freno antibloqueo, control de tracción, y control de estabilidad del vehículo.

Brake torque test A test that is performed with the brakes applied.

Prueba de torsión de frenos Una prueba que se lleva acabo mientras que se aplicacan los frenos.

Bump steer The tendency of the steering to veer suddenly in one direction when one or both front wheels strike a bump.

Cambio de dirección ocacionado por promontorios en el terreno Tendencia de la dirección a cambiar repentinamente de sentido cuando una o ambas ruedas delanteras golpea un promontorio.

Camber adjustment A method of adjusting the inward or outward tilt of a front or rear wheel in relation to the true vertical centerline of the tire.

Ajuste de la combadura Método de ajustar la inclinación hacia adentro o hacia afuera de una rueda delantera o trasera con relación a la línea central vertical real del neumático.

Camber angle The inward or outward tilt of a line through the center of a front or rear tire in relation to the true vertical centerline of the tire and wheel.

Ángulos de combaduras Inclinación hacia adentro o hacia afuera de una línea a través del centro de una rueda delantera o trasera con relación a la línea central vertical real del neumáticoy la rueda.

Caster adjustment A method of adjusting the forward or rearward tilt of a line through the center of the upper and lower ball joints, or lower ball joint and upper strut mount, in relation to the true vertical centerline of the tire and wheel viewed from the side.

Ajuste de comba de eje Método de ajustar la inclinación hacia adelante o hacia atrás de una línea a través del centro de las juntas esféricas superior e inferior, o la junta esférica inferior y el montaje

del montante superior, con relación a la línea central vertical real del neumático y la rueda vista desde la parte lateral.

Caster angle A line through the center of the upper and lower ball joints, or lower ball joint and upper strut mount, in relation to the true vertical centerline of the tire and wheel viewed from the side.

Ángulo de comba de eje Línea a través del centro de las juntas esféricas superior e inferior, o la junta esférica inferior y el montaje del montante superior, con relación a la línea central vertical real del neumático y la rueda vista desde la parte lateral.

Camber The position of an imaginary line through the centers of the upper and lower ball joints or upper strut mount and lower ball joint in relation to the line through the tire center viewed from the front.

Ángulo de verticalidad La posición de una línea imaginaria que atraviesa los centros de las articulaciones esféricas superiores e inferiores o del montaje del montante superior y la articulación esférica inferior en relación con la línea que atraviesa el centro del neumático visto de frente.

Caster The position of an imaginary line through the centers of the upper and lower ball joints or upper strut mount and lower ball joint in relation to the a line through the wheel and spindle center viewed from the side.

Ángulo de convexión La posición de una línea imaginaria que atraviesa los centros de las articulaciones esféricas superiores e inferiores o del montaje del montante superior y la articulación esférica inferior en relación con la línea que atraviesa la rueda y el centro del palier visto de perfil.

Caster offset The distance between the caster line and the center of the front spindle.

Desfasaje del ángulo de convexión La distancia entre la línea de tiro y el centro del palier delantero.

Caster trail An alternate term for caster offset.

Rastro del ángulo de convexión Un término alternativo para desfasaje del ángulo de convexión.

Circlip A round circular clip used as a locking device on components such as front drive axles.

Anillo de pistón Un anillo circular que se utiliza como dispositivo de traba en componentes como los ejes rotativos delanteros.

Claw washer A special locking washer used to retain the tie rods to the rack in some rack and pinion steering gears.

Arandelas de garras Arandela de bloqueo especial que se utiliza para sujetar las barras de acoplamiento a la cremallera en algunos mecanismos de dirección de cremallera y piñón.

"C" lock A thick metal locking device used to lock components such as the rear drive axles in place.

Retenedores en C Un dispositivo de cerrojo de metal grueso que sirve para enclavar los componentes en su lugar, tal como los ejes propulsores traseros.

Clock spring electrical connector A conductive ribbon in a plastic container mounted on top of the steering column that maintains electrical contact between the air bag inflator module and the air bag electrical system.

Conector eléctrico de cuerda de reloj Cinta conductiva envuelta en una cubierta plástica montada sobre la parte superior de la columna de dirección, que mantiene el contacto eléctrico entre la unidad infladora y el sistema eléctrico del Airbag.

Coil spring compressor tool A special tool required to compress a coil spring prior to removal of the spring from the strut.

Herramienta para la compresión del muelle helicoidal Herramienta especial requerida para comprimir un muelle helicoidal antes de remover el muelle del montante.

Cold parts washer Uses a non-heated solution to clean metal parts.

Lavador de partes en frío usa una solución en frío para limpiar las partes de metal.

Collapsible steering column A steering column that is designed to collapse when impacted by the driver in a collision to help reduce driver injury.

Columna de dirección plegable Columna de dirección diseñada para plegarse al ser impactada por el conductor durante una colisión con el propósito de reducir las lesiones que el conductor pueda recibir.

Column-drive EPS An electronically controlled steering gear in which the electric motor supplies torque to the steering column shaft.

Transmisión de columna de GPE (guiado de propulsión eléctrica) El primer paso para diagnosticarlo es verificar la queja de falla del cliente. Haga una prueba de carretera al vehículo si es necesario para identificar la falla.

Computer four wheel aligner A type of wheel aligner that uses a computer to measure wheel alignment angles at the front and rear wheels.

Alineador computerizado de cuatro ruedas Tipo de alineador de ruedas que utiliza una computadora para medir los ángulos de alineación de las ruedas delanteras y traseras.

Continuously variable road sensing suspension (CVRSS) An updated version of the road sensing suspension (RSS).

Suspensión detector continuo de variedades (CVRSS) Un sistema de suspensión detector más avanzada.

Control arm bushing tools Special tools required for control arm bushing removal and replacement.

Herramientas para el buje del brazo de mando Herramientas especiales requeridas para la remoción y el reemplazo del buje del brazo de mando.

Control arm movement monitor A monitor available in some computer wheel aligners. On short-and-long arm front suspensions this feature indicates the required shim thickness to provide the specified camber and caster.

Monitor del movimiento del brazo de mando Un monitor disponible en algunos alineadores de ruedas computerizadas. En las suspensiones delanteras tipo brazo largo-y-corto este elemento indica el espesor de la cuña requerido para proveer el ángulo de la inclinación especificado.

Crocus cloth A very fine paper for polishing or removing small abrasions from metal.

Tela fina de esmeril Papel sumamente fino que se utiliza para pulir o remover pequeñas abrasiones del metal.

Curb riding height The distance between the vehicle chassis and the road surface measured at specific locations.

Altura del cotén del viaje Distancia entre el chasis del vehículo y la superficie del camino medida en puntos específicos.

Data link connector (DLC) An electrical connector for computer system diagnosis mounted under the instrument panel or in the engine compartment.

Conector de enlace de datos Conector eléctrico montado debajo del tablero de instrumentos o en el compartimiento del motor, que se utiliza para la diagnosis del sistema informático.

Datum line A straight reference line such as the top of a dedicated bench system.

Línea de datos Línea recta de referencia, como por ejemplo la parte superior de un sistema de banco dedicado.

Dedicated bench system A heavy steel bed with special fixtures for aligning unitized bodies.

Sistema de banco dedicado Asiento pesado de acero con aparatos especiales que se utiliza para la alineación de carrocerías unitarias.

Diagnostic procedure charts Provide step-by-step diagnostic procedures for specific problems.

Cuadros de procedimientos diagnósticos Proveen los procedimientos diagnóticos paso por paso de los problemas específicos.

Diagnostic trouble codes (DTCs) Codes displayed in digital form that represent faults in a computer-controlled system.

Códigos diagnósticos de averías (DTCs) Los códigos manifestados en forma digital que representan las averías en un sistema controlado por computadora.

Dial indicators A precision-measuring device with a stem and a rotary pointer.

Indicador de cuadrante Dispositivo para medidas precisas con vástago y aguja giratoria.

Digital adjustment photos Photos that are available in some computer-controlled wheel aligners to inform the technician regarding suspension adjustment procedures.

Fotos digitales de ajuste Las fotos que son disponibles en algunos alineadores de ruedas controlados por computadoras para informar a los técnicos en cuanto a los procedimientos de ajustes de la suspensión.

Digital signal processor (DSP) An electronic device in some wheel sensors on computer-controlled wheel aligners.

Procesor de señales digitales Un dipositivo electrónico en algunos sensores de ruedas en los alineadores de ruedas controlados por computadora.

Directional stability The tendency of a vehicle steering to remain in the straight-ahead position when driven straight ahead on a smooth, level road surface.

Estabilidad direccional Tendencia de la dirección del vehículo a permanecer en línea recta al ser así conducido en un camino cuya superficie es lisa y nivelada.

Downshift test A test for chassis vibrations performed with the transmission downshifted.

Prueba de cambio descendente Una prueba de las vibraciones del chasis que se efectúan durante un cambio de carrera de transmisión descendente.

Dynamic stability control (DSC) ECU A computer that receives input signals and controls output functions in a DSC system.

ECU de control de estabilidad dinámico (DSC, en inglés) Una computadora que recibe señales de entrada y controla las funciones de salida en un sistema DSC.

Dynamic wheel balance Refers to proper balance of the tire and wheel assembly during tire and wheel rotation.

Equilibrado dinámico de la rueda Se refiere al equilibrado apropiado del ensamblaje de la llanta y la rueda durante su rotación.

Eccentric camber bolt A bolt with an out-of-round metal cam on the bolt head that may be used to adjust camber.

Perno de combadura excéntrica Perno con una leva metálica con defecto de circularidad en su cabeza, que puede utilizarse para ajustar la combadura.

Eccentric cams Out-of-round metal cams mounted on a retaining bolt with the shoulder of the cam positioned against a component. When the cam is rotated, the component position is changed. Delete Eccentric cams or bushings.

Levas eccéntricas Las levas de metal ovaladas montadas en un perno retenedor con lo saliente de la leva posicionado contra un componente. Cuando se gira la leva cambia la posición del componente.

Electronic brake and traction control module (EBTCM) A module that controls antilock brake, traction control, and vehicle stabilty functions.

Módulo electrónico de control del frenado y tracción (EBTCM) Un módulo que controla las funciones del freno antibloqueo, control de tracción, y control de estabilidad del vehículo.

Electronically controlled orifice (ECO) valve A computer-controlled solenoid valve in the power steering pump that controls fluid flow from the pump to the servotronic valve.

Válvula de orificio controlado electrónicamente (ECO, en inglés) Una válvula solenoide controlada por computadora que se encuentra en la bomba de dirección de potencia que controla el flujo de fluidos desde la bomba hasta la válvula servotrónica.

Electronic suspension control (ESC) An electronically controlled suspension system in which the computer controls strut firmness.

Control electrónico de la suspensión (CES) Los vehículos que se equipan con este sistema pueden tener el tablero de control análogo o digital.

Electronic vibration analyzer (EVA) A tester that measures component vibration.

Analizador electrónico de vibraciones Un detector que mide la vibración de un componente.

Electronic wheel balancer A computer-controlled balancer that provides static and dynamic wheel balance.

Equilibrador de ruedas electrónico Un equilibrador controlado por computadora que provee la equilibración estática y dinámico.

Environmental Protection Agency (EPA) A federal government agency that is responsible for air and water quality in the United States.

Agencia de Protección Ambiental (EPA, en inglés) Una agencia del Gobierno Federal responsable de la calidad del aire y del agua en los Estados Unidos.

Fail-safe mode A mode entered by a computer if the computer detects a fault in the system.

Modo de seguridad Un modo iniciado por la computadora si ésta descubre un fallo en el sistema.

Floor jack A hydraulically operated lifting device for vehicle lifting.

Gato de pie Dispositivo activado hidráulicamente que se utiliza para levantar un vehículo.

Flow control valve A special valve that controls fluid movement in relation to system demands.

Válvula de control de flujo Válvula especial que controla el movimiento del fluido de acuerdo a las exigencias del sistema.

Fluorescent trouble lights Contain fluorescent-type bulbs.

Luces de peligro fluorescentes Incluyen bombillas de tipo fluorescente.

Frame flange The upper or lower horizontal edge on a vehicle frame.

Brida del armazón Borde horizontal superior o inferior en el armazón del vehículo.

Frame web The vertical side of a vehicle frame.

Malla del armazón Lado vertical del armazón del vehículo.

Front and rear wheel alignment angle screen A display on a computer wheel aligner that provides readings of the front and rear wheel alignment angles.

Pantalla para la visualización del ángulo de alineación de las ruedas delanteras y traseras Representación visual en una computadora para alineación de ruedas que provee lecturas de los ángulos de alineación de las ruedas delanteras y traseras.

Geometric centerline An imaginary line through the exact center of the front and rear wheels.

Línea central geométrica Línea imaginaria a través del centro exacto de las ruedas delanteras y traseras.

Hazard Communication Standard A forerunner to the Right-To-Know laws published by the Occupational Health and Safety Administration (OSHA).

Estándar de comunicación de riesgos Un precursor de las leyes del derecho a saber publicado por la Administración de Seguridad y Salud Ocupacional (OSHA, en inglés).

Heavy spot Is a location in a tire with excessive weight.

Zona Dura es un lugar en la llanta con peso excesivo.

High-frequency transmitter An electronic device that sends high-frequency voltage signals to a receiver. Some wheel sensors on computer-controlled wheel aligners send high-frequency signals to a receiver in the wheel aligner.

Transmisor de alta frecuencia Un dispositivo electrónico que manda las señales de voltaje de alta frecuencia a un receptor. Algunos sensores de ruedas en los alineadores controlados por computadora mandan señales de alta frecuencia a un receptor en el alineador de ruedas.

History code A fault code in a computer that represents an intermittent defect.

Código histórico Código de fallo en una computadora que representa un defecto intermitente.

Hot cleaning tank Uses a heated solution to clean metal parts.

Tanque de limpieza en caliente Usa una solución caliente para limpiar las partes de metal.

Hydraulic press A hydraulically operated device for disassembling and assembling components that have a tight press-fit.

Prensa hidráulica Dispositivo activado hidráulicamente que se utiliza para desmontar y montar componentes con un fuerte ajuste en prensa.

Ignitable A liquid, solid, or a gas that can be set on fire spontaneously or by an ignition source.

Inflamable Un líquido, sólido o gas que se puede encender espontáneamente o mediante una fuente de ignición.

Incandescent bulb-type trouble lights Contain incandescent-type bulbs.

Luces de peligro con bombilla de tipo incandescente Incluyen bombillas de tipo incandescente.

Included angle The sum of the camber and steering axis inclination (SAI) angles.

Ángulo incluido La suma del ángulo de inclinación de la comba y de ángulo de inclinación del eje de dirección (SAI).

Integral reservoir A reservoir that is joined with another component such as a power steering pump.

Tanque integral Tanque unido a otro componente, como por ejemplo una bomba de la dirección hidráulica.

International system (SI) A system of weights and measures.

Sistema internacional Sistema de pesos y medidas.

Lateral axle sideset The amount that the rear axle is moved straight sideways in relation to the front axle.

Desplazamiento lateral del eje La cantidad que el eje trasero está desplazado directamente hacia un lado en relación al eje delantero.

Lateral chassis movement Movement from side to side.

Movimiento lateral del chasis Movimiento de un lado a otro.

Lateral tire runout The variation in side-to-side movement.

Desviación lateral del neumático Variación del movimiento de un lado a otro.

Machinist's rule A steel ruler used for measuring short distances. These rulers are available in USC or metric measurements.

Regla para mecánicos Regla de acero que se utiliza para medir distancias cortas. Dichas reglas están disponibles en medidas del USC o en medidas métricas.

Main menu A display on a computer wheel aligner from which the technician selects various test procedures.

Menú principal Representación visual en una computadora para alineación de ruedas de la que el mecánico puede elegir varios procedimientos de prueba.

Magnetic wheel alignment gauge A gauge that may be attached magnetically to the wheel hub to indicate some wheel alignment angles.

Indicador de alineación de rueda magnética Un indicador que se puede adjuntar magnéticamente al buje de la rueda para indicar algunos ángulos de alineación de la rueda.

Manual test A shock absorber test in which the lower end of the shock is disconnected from the suspension.

Prueba manual Una prueba del amortiguador en la cual el extremo inferior del amortiguador se disconecta de la suspensión.

Material safety data sheets (MSDSs) List appropriate information about hazardous materials.

Hojas de datos de seguridad del material (MSDS, en inglés) Lista con información adecuada acerca de materiales peligrosos.

Memory steer The tendency of the vehicle steering not to return to the straight-ahead position after a turn but to keep steering in the direction of the turn.

Dirección de memoria Tendencia de la dirección del vehículo a no regresar a la posición de línea recta después de un viraje, sino a continuar girando en el sentido del viraje.

Molybdenum disulphide lithium-based grease A special lubricant containing molybdenum disulphide and lithium that may be used on some steering components.

Grasa de bisulfuro de molibdeno con base de litio Lubricante especial compuesto de bisulfuro de molibdeno y litio que puede utilizarse en algunos componentes de la dirección.

Multipull unitized body straightening system A hydraulically operated system that pulls in more than one location when straightening unitized bodies.

Sistema de tiro múltiple para enderezar la carrocería unitaria Sistema activado hidráulicamente que tira hacia más de una dirección al enderezar carrocerías unitarias.

Multipurpose dry chemical fire extinguisher Contains a dry chemical powder used to extinguish various types of fires.

Extintor de incendios multipropósito de polvo químico seco Contiene un polvo químico seco que se utiliza para apagar diversos tipos de incendios.

National Institute for Automotive Service Excellence (ASE) An organization that provides voluntary automotive technician certification in eight areas of expertise.

Instituto Nacional para la excelencia en la reparación de automóviles Organización que provee una certificación voluntaria de mecánico de automóviles en ocho áreas diferentes de especialización.

Neutral coast-down test A chassis vibration test performed while the vehicle is coasting in neutral.

Prueba de marcha desembragado Una prueba de vibración del chasis que se efectúa mientras que el vehículo marcha desembragado.

Neutral run-up test A vibration test performed by accelerating the engine with the transmission in neutral.

Prueba de aceleración desembragado Una prueba de vibración que se efectúa acelerando el motor con la transmisión desembragada.

OBD II computer systems Have monitoring capabilities and inform the driver if emission levels exceed 1.5 time the normal levels for that vehicle year.

Sistemas de computación OBD II Cuentan con capacidades de monitoreo e informan al conductor si los niveles de emisiones superan 1,5 veces los niveles normales para ese año vehicular.

Occupational Safety and Health Act (OSHA) A federal government agency and related laws in the United States that are responsible for ensuring safe and healthful working conditions.

Administración de Seguridad y Salud Ocupacional (OSHA, en inglés) Una agencia del Gobierno Federal, y sus leyes relacionadas, en los Estados Unidos, responsable de garantizar condiciones de trabajo seguro y saludable.

Onboard Diagnostic II (OBD II) Systems are a type of computer system mandated on cars and light trucks since 1996. OBD II systems have a number of mandated standardized features, including several monitoring systems in the PCM.

Sistemas de Capacidad de diagnóstico a bordo II (CDB II) Son un tipo de sistema computarizado obligatorio en automóviles y camionetas ligeras desde 1996. Los sistemas CDB II tienen un número de características estandarizadas obligatorias que incluyen varios sistemas de monitoreo en el módulo de control del motor (MCM).

On-demand DTCs Diagnostic trouble codes that represent intermittent faults in some computer-controlled systems.

DTCs a solicitud Los códigos de fallos diagnósticos que representan los fallos intermitentes en algunos sistemas controlados por computadora.

Oversteer The tendency of a vehicle to turn sharper than the turn selected by the driver.

Sobreviraje Tendencia de un vehículo a girar más de lo que el conductor desea.

Part-finder database Information available in some computer wheel aligners that allows the technician to access part numbers and prices from many undercar parts manufacturers.

Datos para localización de partes La información disponible en algunos alineadores de ruedas electrónicos que permite que el técnico tenga acceso a los números y precios de partes de muchos de los fabricantes de partes del carro inferior.

Pitman arm puller A special puller required to remove a pitman arm.

Extractor del brazo pitman Extractor especial requerido para la remoción de un brazo pitman.

Plumb bob A weight with a sharp, tapered point that is suspended and centered on a string.

Plomada Balanza con un extremo cónico puntiagudo, suspendida y centrada en una hilera.

Ply separation A parting of the plies in a tire casing.

Separación de estrias División de las estrias en la cubierta de un neumático.

Power steering pressure gauge A gauge and valve with connecting hoses for checking power steering pump pressure.

Calibrador de presión de la dirección hidráulica Calibrador y válvula con mangueras de conexión utilizadas para verificar la presión de la bomba de la dirección hidráulica.

Powertrain control module (PCM) A computer that controls engine and possibly transmission functions.

Unidad de control del tren transmisor de potencia Computadora que controla las funciones del motor y posiblemente las de la transmisión.

Prealignment inspection A check of steering and suspension components prior to a wheel alignment.

Inspección antes de una alineación Verificación de los componentes de la dirección y de la suspensión antes de llevarse a cabo una alineación de ruedas.

Preliminary inspection screen A display on a computer wheel aligner that allows the technician to check and record the condition of many suspension and steering components.

Pantalla para la visualización durante una inspección preliminar Representación visual en una computadora para alineación de ruedas que le permite al mecánico revisar y anotar la condición de un gran número de componentes de la suspensión y de la dirección.

Pressure gauge A gauge that may be connected to a pressure source, such as a power steering pump, to determine pump condition.

Indicador de presión Un manómetro que se puede conectar a una fuente de presión, tal como la bomba de la dirección hidráulica, para determinar la condición de la bomba.

Pressure relief valve A valve designed to limit pressure on a pump, such as a power steering pump.

Válvula de relieve de presión Una válvula diseñada para limitar la presión en una bomba, tal como en una bomba de dirección hidráulica.

Programmed ride control (PRC) A computer-controlled suspension system in which the computer operates an actuator in each strut to control strut firmness.

Control programado del viaje Sistema de suspensión controlado por computadora en el que la computadora opera un accionador en cada uno de los montantes para controlar la firmeza de los mismos.

Rack-drive electronic power steering The electronic power steering (EPS) light in the instrument panel should be illuminated when the ignition switch is turned on, in vehicles with rack-drive electronic power steering.

Cremallera de dirección GPE (guiado de propulsión electrónica) La luz del guiado de propulsión electrónica (GPE) en el tablero de control debe iluminarse cuando el selector de encendido se prende en vehículos con cremallera de dirección GPE.

Radial runout The variations in diameter of a round object such as a tire.

Desviación radial Variaciones en el diámetro de un objeto circular, como por ejemplo un neumático.

Reactive Resource Conservation and Recovery Act (RCRA) Provides specific laws regarding hazardous waste disposal.

Acta de Conservación y Recuperación de Recursos Reactivos (RCRA, en inglés) Proporciona leyes específicas respecto de la eliminación de desechos peligrosos.

Rear axle offset A condition in which the complete rear axle assembly has turned so one rear wheel has moved forward and the opposite rear wheel has moved rearward.

Desviación del eje trasero Condición que ocurre cuando todo el conjunto del eje trasero ha girado de manera que una de las ruedas traseras se ha movido hacia adelante y la opuesta se ha movido hacia atrás.

Rear axle sideset A condition in which the rear axle assembly has moved sideways from its original position.

Resbalamiento lateral del eje trasero Condición que ocurre cuando el conjunto del eje trasero se ha movido lateralmente desde su posición original.

Rear main steering angle sensor An input sensor in the rear steering actuator of an electronically controlled four-wheel steering system.

Sensor principal del ángulo de la dirección trasera Sensor de entrada en el accionador de la dirección trasera de un sistema de dirección en las cuatro ruedas controlado electrónicamente.

Rear steering center lock pin A special pin used to lock the rear steering during specific service procedures in an electronically controlled four-wheel steering system.

Pasador de cierre central de la dirección trasera Pasador especial que se utiliza para bloquear la dirección trasera durante procedimientos de reparación específicos en un sistema de dirección en las cuatro ruedas controlado electrónicamente.

Rear sub steering angle sensor An input sensor in the rear steering actuator of a four-wheel steering system.

Sensor auxiliar del ángulo de la dirección trasera Sensor de entrada en el accionador de la dirección trasera de un sistema de dirección en las cuatro ruedas.

Rear wheel camber The tilt of a line through the center of a rear tire and wheel in relation to the true vertical centerline of the tire and wheel.

Comba de la rueda trasera La inclinación de una línea que atraviesa el centro del neumático y la rueda en relación al eje mediano verdadero del neumático y la rueda.

Rear wheel toe The toe setting on the rear wheels.

Ángulo de inclinación de la rueda trasera El ajuste del ángulo de inclinación en las ruedas traseras.

Rear wheel tracking Refers to the position of the rear wheels in relation to the front wheels.

Encarrilamiento de las ruedas traseras Se refiere a la posición de las ruedas traseras con relación a las ruedas delanteras.

Rebound bumpers Rubber stops that prevent metal-to-metal contact between the suspension and the chassis when a wheel strikes a road irregularity and the suspension moves fully upward.

Paragolpes de rebotes Topes de cauchos que previene el contacto de metal a metal entre la suspensión y el chasis cuando una rueda golpea una irregularidad en el camino y la suspensión se mueva totalmente hacia arriba.

Receiver An electronic device on an aligner that receives signals from the wheel sensors.

Receptor Un dispositivo electrónico de una alienador computerizado de cuatro ruedas que recibe las señales de los sensores de las ruedas.

Remote reservoir A container containing fluid that is mounted separately from the fluid pump.

Tanque remoto Recipiente lleno de líquido que se monta separado de la bomba del fluido.

Ribbed V-belt A belt containing a series of small "V" grooves on the underside of the belt.

Correa nervada en V Correa con una serie de ranuras pequeñas en forma de "V" en la superficie inferior de la misma.

Ride height The distance from a specified chassis location to the road surface.

Altura del viaje La distancia de un punto específico del chasis a la superficie del camino.

Ride height screen A display on a computer wheel aligner that illustrates the locations for ride height measurement.

Pantalla para la visualización de la altura del viaje Representación visual en una computadora para alineación de ruedas que muestra los puntos donde se mide la altura del viaje.

Right-to-Know Laws List the worker's rights regarding the handling of hazardous waste materials.

Leyes del Derecho a saber Lista de los derechos de los trabajadores respecto del manejo de materiales de desecho peligrosos.

Rim clamps Special clamps designed to clamp on the wheel rims and allow the attachment of alignment equipment such as the wheel units on a computer wheel aligner.

Abrazaderas de la llanta Abrazaderas especiales diseñadas para sujetar las llantas de las ruedas y así permitir la fijación del equipo de alineación, como por ejemplo las unidades de la rueda en una computadora para alineación de ruedas.

Road feel A feeling experienced by a driver during a turn when the driver has a positive feeling that the front wheels are turning in the intended direction.

Sensación del camino Sensación experimentada por un conductor durante un viraje cuando está completamente seguro de que las ruedas delanteras están girando en la dirección correcta.

Road test A driving procedure used to diagnose specific vehicle problems.

Prueba de camino Un procedimiento de conducción que se usa para diagnosticar los problemas específicos del vehículo.

Safety and gateway module (SGM) Operates the servotronic valve and the electronically controlled orifice valve in some power steering systems.

Módulo de puerta de enlace y seguridad (SGM, en inglés) Opera la válvula servotrónica y la válvula de orificio controlado electrónicamente en algunos sistemas de dirección de potencia.

Safety stands May be called jack stands.

Bases de seguridad Pueden también llamarse bases del gato.

Scan tool A digital computer system tester used to read trouble codes and perform other diagnostic functions.

Exploradore Un probador del sistema de computadora digital que sirve para leer los códigos de errores y para executar otras funciones diagnósticas.

Seal drivers Designed to maintain even contact with a seal case and prevent seal damage during installation.

Empujadores para sellar Diseñados para mantener un contacto uniforme con el revestimiento de la junta de estanqueidad y evitar el daño de la misma durante el montaje.

Section modulus The measurement of a frame's strength based on height, width, thickness, and the shape of the side rails.

Coeficiente de sección Medida de la resistencia de un armazón, basada en la altura, el ancho, el espesor y la forma de las vigas laterales.

Sector shaft lash Refers to the movement between the sector teeth and ball nut teeth.

Coletazo del eje de sector Se refiere al movimiento entre el dentado del sector y el de la tuerca esférica.

Serpentine belt A ribbed V-belt drive system in which all the belt-driven components are on the same vertical plane.

Correa serpentina Sistema de transmisión con correa nervada en V en el que todos los componentes accionados por una correa se encuentran sobre el mismo plano vertical.

Service check connector A diagnostic connector used to diagnose computer systems. A scan tool may be connected to this connector.

Conector para la revisión de reparaciones Conector diagnóstico que se utiliza para diagnosticar sistemas informáticos. A dicho conector se le puede conectar un verificador de exploración.

Servotronic valve A computer-controlled valve in an active steering system that controls power steering pump pressure in relation to vehicle speed.

Válvula servotrónica Una válvula controlada por computadora en un sistema de dirección activo que controla la presión de la bomba de dirección de potencia de acuerdo con la velocidad del vehículo.

Setback Occurs when one front or rear wheel is driven rearward in relation to the opposite front or rear wheel.

Retroceso Condición que ocurre cuando una de las ruedas delanteras se mueve hacia atrás con relación a la rueda delantera opuesta.

Sheared injected plastic Is inserted into steering column shafts and gearshift tubes to allow these components to collapse if the driver is thrown against the steering column in a collision.

Plástico cortado inyectado Insertado en los árboles de la columna de dirección y en los tubos del cambio de engranajes de velocidad para permitir que estos componentes se pleguen si la columna de dirección es impactada por el conductor durante una colisión.

Shim display screen A display on a computer wheel aligner that shows the technician the thickness and location of the proper shims for rear wheel alignment.

Pantalla de laminillas de ajuste Una presentación en un alineador de ruedas que demuestra al técnico el espesor y localización de las laminillas apropriadas para alineación de las ruedas traseras.

Single-pull unitized body straightening system Hydraulically operated equipment that pulls in one location while straightening unitized bodies.

Sistema enderezador de tiro único para la carrocería unitaria Sistema activado hidráulicamente que tira hacia una dirección al enderezar carrocerías unitarias.

Slip plates Plates that are placed under the rear wheels during a wheel alignment to allow rear wheel movement during rear suspension adjustments.

Placas de patinaje Las placas que se colocan debajo de las ruedas traseras durante un alineación de ruedas traseras para permitir el movimiento de las ruedas traseras durante el ajuste de la suspensión trasera.

Slow acceleration test A chassis vibration test performed by slowly accelerating the vehicle.

Prueba de aceleración lenta Una prueba de vibración del chasis que se efectúa por medio de una aceleración lenta del vehículo.

Soft-jaw vise A vise equipped with soft metal, such as copper, in the jaws.

Tornillo con tenacilla maleable Tornillo equipado con un metal blando, como por ejemplo cobre, en las tenacillas.

Specifications menu A display on a computer wheel aligner that allows the technician to select, enter, alter, and display vehicle specifications.

Menú de especificaciones Representación visual en una computadora para alineación de ruedas que le permite al mecánico seleccionar, introducir datos, cambiar e indicar especificaciones referentes al vehículo.

Splice pack A special connector in a vehicle network that may be disconnected to isolate specific components for diagnostic purposes.

Paquete de empalmes Un conector especial en una red de vehículos que se puede desconectar para aislar componentes específicos con fines de diagnóstico.

Spring compressing tools Tools that are used to compress a coil spring during the removal and replacement procedure.

Herramientas de compresión de resortes Las herramientas que se usan para comprimir un resorte helicoidal durante el procedimiento de remoción y refacción.

Spring insulators Rings usually made from plastic and positioned on each end of a coil spring to reduce noise and vibration transfer to the chassis.

Aisladores de muelles Anillos, por lo general fabricados de plástico y colocados a ambos extremos de un muelle helicoidal, que se

utilizan para disminuir la transferencia de ruido y de vibración al chasis.

Spring silencers Plastic spacers placed between spring leaves to reduce noise.

Amortiguadores de los resortes Las arandelas de plástico puestas entre los muelles de hojas para disminuir el ruido.

Stabilizer bar A round steel bar connected between the front or rear lower control arms that reduces body sway.

Barra estabilizadora Barra circular de acero contectada entre los brazos de mando delantero o trasero que disminuye la oscilación lateral de la carrocería.

Standing acceleration test A vibration test performed during moderate vehicle acceleration.

Prueba de acceleración fijo Una prueba de vibración que se efectúa durante una aceleración moderada del vehículo.

Static balance Refers to the balance of a tire and wheel at rest.

Equilibrio estático Refiere al equilibrio de una rueda y de un neumático y una rueda cuando se ha detenido la marcha del vehículo.

Steering axis inclination (SAI) The tilt of a line through the center of the upper and lower ball joints or through the center of the lower ball joint and the upper strut mount in relation to the true vertical centerline of the tire and wheel.

Inclinación del eje de dirección (SAI) La inclinación de una línea que atraviesa el centro de las juntas esféricas superiores e inferiores o por el centro de la junta esférica inferior y el montaje del tirante superior en relación al eje mediano verdadero del neumático y de la rueda.

Steering effort The amount of effort required by the driver to turn the steering wheel.

Esfuerzo de dirección Amplitud de esfuerzo requerido por parte del conductor para girar el volante de dirección.

Steering effort imbalance Occurs when more effort is required to turn the steering wheel in one direction than in the opposite direction.

Desequilibrio del esfuerzo en dirección Ocurre cuando se requiere más esfuerzo para girar la rueda en una dirección que en la dirección opuesta.

Steering input test A vibration test performed while driving the vehicle through turns.

Prueba de entrada de dirección Una prueba de vibración que se efectúa mientras que el vehículo completa los virajes.

Steering pull The tendency of the steering to pull to the right or left when the vehicle is driven straight ahead on a smooth, straight road surface.

Tiro de la dirección Tendencia de la dirección a desviarse hacia la derecha o hacia la izquierda mientras se conduce el vehículo en línea recta en un camino cuya superficie es lisa y nivelada.

Steering wheel free play The amount of steering wheel movement before the front wheels begin to turn.

Juego libre del volante de dirección Amplitud de movimiento del volante de dirección antes de que las ruedas delanteras comiencen a girar.

Steering wheel locking tool A special tool used to lock the steering wheel during certain wheel alignment procedures.

Herramienta para el cierre del volante de dirección Herramienta especial que se utiliza para bloquear el volante de dirección durante ciertos procedimientos de alineación de ruedas.

Stethoscope A special tool that amplifies sound to help diagnose noise location.

Estetoscopio Herramienta especial que amplifica el sonido para ayudar a diagnosticar la procedencia de los ruidos.

Struts Similar to shock absorbers, but struts also support the steering knuckle.

Montantes Parecidos a los amortiguadores, pero los montantes tambien sostiene el muñon de dirección.

Strut cartridge The inner components in a strut that may be replaced rather than replacing the complete strut.

Cartucho del montante Componentes internos de un montante que pueden ser reemplazados en vez de tener que reemplazarse todo el montante.

Strut chatter A chattering noise as the steering wheel is turned, often caused by a binding upper strut mount.

Vibración del montante Rechinamiento producido mientras se gira el volante de dirección. A menudo ocasionado por el trabamiento del montaje del montante superior.

Strut rod A rod connected from the lower control arm to the chassis to prevent forward and rearward control arm movement.

Varilla del montante Varilla conectada del brazo de mando inferior al chasis que se utiliza para evitar el movimiento hacia adelante o hacia atrás del brazo de mando.

Strut tower A circular, raised, reinforced area inboard of the front fenders that supports the upper strut mount and strut assembly.

Torre del montante Área circular, elevada y reinforzada en la parte interior de los guardafangos delanteros que apoya el conjunto del montante y montaje del montante superior.

Sunburst cracks Cracks that radiate outward from an opening in the vehicle frame.

Grietas radiales Las grietas que radian hacia afuera desde una apertura en el armazón del vehículo.

Suspension adjustment link An adjustable link connected horizontally from the suspension to the chassis.

Biela de ajuste de la suspensión Una biela ajustable conectada horizontalmente de la suspensión al chasis.

Symmetry angle measurements On some computer-controlled wheel aligners, they help the technician determine if out-of-specifications readings may have been caused by collision or frame damage.

Medidas de simetría de los ángulos En algunos alineadores de ruedas controlados por computadora, ayudan al técnico en determinar si las medidas fuera de specificación puedan haber sido causadas por una colisión o un daño al bastidor.

Tapered-head bolts A bolt with a taper on the underside of the head.

Pernos de cabeza cónica Perno con una cabeza cuya superficie inferior es cónica.

Thrust line A line positioned at a 90° angle to the rear axle and projected toward the front of the vehicle.

Línea de empuje Línea colocada a un ángulo de 90° con relación al eje trasero y proyectada hacia la parte frontal del vehículo.

Tie-rod end and ball joint puller A special puller designed for removing tie-rod ends and ball joints.

Extractor para la junta esférica y el extremo de la barra de acoplamiento Extractor especial diseñado para la remoción de las juntas esféricas y los extremos de barras de acoplamiento.

Tie-rod sleeve adjusting tool A special tool required to rotate tie-rod sleeves without damaging the sleeve.

Herramienta para el ajuste del manguito de la barra de acoplamiento Herramienta especial requerida para girar los manguitos de las barras de acoplamiento sin estropearlos.

Tire changer Equipment used to dismount and mount tires on wheel rims.

Cambiador de neumáticos Equipo que se utiliza para desmontar y montar los neumáticos en las llantas de las ruedas.

Tire conicity Occurs when the tire belt is wound off-center in the manufacturing process creating a cone-shaped belt, which results in steering pull.

Conicidad del neumático Condición que ocurre cuando la correa del neumático se devana fuera del centro durante el proceso de fabricación creando así una correa en forma cónica y trayendo como resultado el tiro de la dirección.

Tire inspection screen A screen on a computer-controlled wheel aligner that allows the technician to enter the condition of each vehicle tire.

Pantalla de inspección de los neumáticos Una pantalla en un alineador de ruedas controlado por computadora que permite que el técnico anote la condición de cada neumático del vehículo.

Tire rotation Involves moving each tire and wheel to a different location on the vehicle to increase tire life.

Rotación de los neumáticos Involucra moviendo cada neumático y rueda a una posición diferente en el vehículo para prolongar la vida del neumático.

Tire thump A pounding noise as the tire and wheel rotate, usually caused by improper wheel balance.

Ruido sordo del neumático Ruido similar al de un golpe pesado que se produce mientras el neumático y la rueda están girando. Por lo general este ruido lo ocasiona el desequilibrio de la rueda.

Tire tread depth gauge A special tool required to measure tire tread depth.

Calibrador de la profundidad de la huella del neumático Herramienta especial requerida para medir la profundidad de la huella del neumático.

Tire vibration Vertical or sideways tire oscillations.

Vibración del neumático Oscilaciones verticales o laterales del neumático.

Toe gauge A special tool used to measure front or rear wheel toe.

Calibrador del tope Herramienta especial que se utiliza para medir el tope de las ruedas delanteras o traseras.

Toe-in A condition in which the distance between the front edges of the tires is less than the distance between the rear edges of the tires.

Convergencia Condición que ocurre cuando la distancia entre los bordes frontales de los neumáticos es menor que la distancia entre los bordes traseros de los mismos.

Toe-out A condition in which the distance between the front edges of the tires is more than the distance between the rear edges of the tires.

Divergencia Condición que ocurre cuando la distancia entre los bordes delanteros de los neumáticos es mayor que la distancia entre los bordes traseros de los mismos.

Torque steer The tendency of the steering to pull to one side during hard acceleration on front wheel drive vehicles with unequal length front drive axles.

Dirección de torsión Tendencia de la dirección a desviarse hacia un lado durante una aceleración rápida en un vehículo de tracción delantera con ejes de mando desiguales.

Total toe The sum of the toe angles on both wheels.

Tope total Suma de los ángulos del tope en ambas ruedas.

Track gauge A long straight bar with adjustable pointers used to measure rear wheel tracking in relation to the front wheels.

Calibrador del encarrilamiento Barra larga y recta con agujas ajustables que se utiliza para medir el encarrilamiento de las ruedas traseras con relación a las ruedas delanteras.

Tram gauge A long, straight bar with adjustable pointers used to measure unitized bodies.

Calibrador del tram Barra larga y recta con agujas ajustables que se utiliza para medir carrocerías unitarias.

Tread wear indicators Raised portions near the bottom of the tire tread that are exposed at a specific tread wear.

Indicadores del desgaste del neumático Secciones elevadas cerca de la parte inferior de la huella del neumático que quedan expuestas cuando la huella alcanza una cantidad de desgaste específica.

Trim height The normal chassis riding height on a computer-controlled air suspension system.

Altura equilibrada Altura normal de viaje del chasis en un sistema de suspensión controlado por computadora.

Turning radius gauge A gauge with a degree scale mounted on turntables under the front wheels.

Calibrador del radio de giro Calibrador con una escala de grados montado sobre plataformas giratorias debajo de las ruedas delanteras.

Turntable A mechanical device placed under each front wheel during a wheel alignment to allow the front wheels to be turned in each direction to measure various front suspension angles.

Plataforma giratoria Un dispositivo mecánico colocado debajo de cada rueda delantera durante la alineación de ruedas para permitir girar las ruedas delanteras en cada dirección para medir varios ángulos de la suspensión delantera.

Understeer The tendency of a vehicle not to turn as much as desired by the driver.

Dirección pobre Tendencia de un vehículo a no girar tanto como lo desea el conductor.

U.S. Customary (USC) system A system of weights and measures patterned after the British system.

Sistema usual estadounidense (USC) Sistema de pesos y medidas desarrollado según el modelo del Sistema Imperial Británico.

Vacuum hand pump A mechanical pump with a vacuum gauge and hose used for testing vacuum-operated components.

Bomba de vacío manual Bomba mecánica con un calibrador de vacío y una manguera que se utiliza para probar componentes a depresión.

Vehicle Dynamic Suspension (VDS) Is a computer-controlled air suspension system used on some current model vehicles.

Suspensión dinámica del vehículo (SDV) Es un sistema de suspensión de aire que se usa en algunos vehículos de modelo reciente.

Vehicle lift A hydraulically or air-operated mechanism for lifting vehicles.

Levantamiento del vehículo Mecanismo activado hidráulicamente o por aire que se utiliza para levantar vehículos.

Vehicle wander The tendency of the steering to pull to the right or left when the vehicle is driven straight ahead on a straight road.

Desviación de la marcha del vehículo Tendencia de la dirección a desviarse hacia la derecha o hacia la izquierda cuando se conduce el vehículo en línea recta en un camino cuya superficie es lisa.

V-type belt A drive belt with a V shape.

Correa en V Una correa de transmisión en forma de V.

Woodruff key A half-moon-shaped metal key used to retain a component, such as a pulley, on a shaft.

Chaveta woodruff Chaveta de metal en forma de media luna que se utiliza para sujetar un componente, como por ejemplo una roldana, en un árbol.

Workplace hazardous materials information systems (WHMIS) Are similar to MSDS sheets and they provide information regarding the handling of hazardous waste materials.

Sistemas de información acerca de materiales peligrosos en el lugar de trabajo (WHMIS, en inglés) Son similares a las hojas de datos MSDS y brindan información acerca del manejo de materiales de desecho peligrosos.

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